A HANDBOOK OF

BRIQUETTING.

VOLUME II.

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A HANDBOOK OF
BRIQUETTING

BY

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DIRECTOR OF INDUSTRIES Bengal

FOREWORD.

VOLUME I. of this handbook has dealt mainly with the briquetting of mineral fuels, a sphere of work which stands in the closest relationship with the mining of pit and brown coals, with the dressing and sale of coal, and also with the cutting and utilisation of peat.

Part I. embraces the "Production of Coal Briquettes," Part II. the "Production of Brown-Coal Briquettes and Wet-Compressed Blocks," while the production of briquettes from peat, wood waste, and other non-metallic organic or inorganic materials is dealt with in an Appendix.

Closely related to the mining, dressing, and utilisation of ores, more especially iron ores, this branch of the subject is also of some importance in the utilisation of the swarf obtained in the various machining operations carried out on iron, steel, and other metals and alloys.

Although this phase of briquetting deals with the conversion of finely divided or powdery materials into lump form, and notwithstanding that many of the binding materials and mechanical appliances used in the briquetting of coals are, or could be, applied equally well here, it appears to be advisable to deal with the case of ores, etc., separately, and to refer to the descriptions, illustrations, and reports contained in Vol. I whenever necessary, because the nature of the materials dealt with differs very considerably in the two cases. Further, the resulting briquettes have to fulfil totally different requirements as a result of the different objects of their application.

In addition to briquetting proper, agglomeration or sintering of ores and metallurgical products is also dealt with. This process consists of converting suitable fine material into lumps adapted to the particular smelting process, without calling in the aid of the processes of moulding and compression.

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ERRATUM.

On page 34, line 13, "oxidation" *should read* "reduction."

DIRECTOR OF INDUSTRIES
Bengal

PART III.

BRIQUETTING AND AGGLOMERATION OF ORES, METALLURGICAL PRODUCTS, METAL SWARF, AND SIMILAR MATERIALS.

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BRIQUETTES AND BRIQUETTING.

SECTION I

VARIOUS METALLIC BRIQUETTING MATERIALS. REASONS FOR, AND OBJECTS OF BRIQUETTING THEM. CHARACTERISTICS OF GOOD BRIQUETTES. BRIQUETTE TESTING.

A. VARIOUS METALLIC BRIQUETTING MATERIALS.

1. Ores

ORES are of prime importance. They have either to be worked up in the rough, as dressed products (slimes, concentrates, etc.), as roasted ores, or, in some cases, in the form of residues from the lixiviation of such products.

(*a*) **Crude Ores**, as such, are seldom considered for direct briquetting or agglomeration except in cases when, in addition to lumps of ore, there exist considerable quantities of finely divided or moist material containing enough metal to dispose of the necessity for special dressing. Such fine material may arise during the mining operations, or may be produced subsequently by breakage and attrition of the lumps during loading and unloading, during long journeys by rail or sea, or during prolonged storage in large open spaces.

This applies, for example, to many of the rich magnetic iron ore and red hematite deposits occurring in Sweden, Spain, South Russia, North America, and other places. The bulk of these ores is shipped long distances, considerable quantities being sent to Germany. It also applies to the very soft iron

ores of the Mesabi district; to the deposits of finely divided oolitic clay or chalky-argillaceous brown iron ores occurring in Upper Silesia, Gross-Ilsede, the Lahn district, the Crimea, Bavaria, Scotland, and other parts of the world; the powdery manganese ores occurring in the Caucasus and at Giessen. Calamine (for zinc smelting), bauxite, and china clay (for the production of aluminium) also come under the same heading.

Up to the present only a relatively small proportion of these and other similar suitable ores have been subjected to the process of briquetting, but of late there has been an increased tendency towards the application of brick-making or agglomeration at the mines, at the main stockyards for ore exportation, or even at the smelting works. The poor fine oolitic brown hematites, obtained in not inconsiderable quantities at the Minette pits of Lorraine and Luxembourg, are not specially suitable for briquetting, since their lime content would lead to re-disintegration in the blast furnace, and methods of briquetting to overcome this difficulty would be far too costly.

(*b*) **Prepared Ores** refer not so much to the smalls separated from the lumps by the simple process of sieving, but rather to the concentrated fine ores which, after a more or less fine pulverisation of the rough material, have been separated from admixed gangue or foreign ores by means of a flotation, magnetic, or similar process. These enriched ores are obtained in the form of sands, meals, or slimes, and are generally called "concentrates."

Considerable quantities of these concentrates are already briquetted in Europe, principally in Central Sweden and North Norway, where several of the iron ore deposits, more particularly magnetic ores, are becoming exhausted, but still contain considerable quantities of poorer ores (containing from 50 to below 30 per cent. of iron) which do not permit of direct smelting. The whole of the output of rough ore is first broken into pieces of a suitable size, then finely ground, and the powder concentrated electromagnetically until its iron content is upwards of 60 per cent. Such a material can yield briquettes of a very high value.

In this way 258,000 tons of poor ores were worked up into 131,000 tons of concentrates in 1906 in Sweden alone. Of this quantity, more than half was briquetted in Sweden, some was worked up in Germany, and the remainder treated elsewhere.

In Germany, too, there are a large number of deposits of materials deficient in iron—ferruginous sandstones containing 11 to 12 per cent. of iron, for example, cover many square miles—which could be worked up into useful and valuable products by suitable processes of magnetic concentration and briquetting similar to those applied in Sweden. The reason for scarcely ever doing this at the present time lies in the absence of necessity.

So long as rich ores can be obtained cheaply from other countries, there is little object in going to the extra expense involved in obtaining iron from poor

native ores. Nevertheless, the advice of H. Wedding should be followed, and timely consideration given to the subject, so that the sudden development of unexpected conditions, such as the impost of taxes, legislation against export, the outbreak of war, etc., should be amply provided for. At the same time considerable help would be given to the development of the German pig-iron industry. According to an estimate by the editor of *Stahl und Eisen*, the German pig-iron industry should grow at the rate of 6·3 per cent. per annum—from 12,478,000 tons in 1906 to 29,110,000 tons in 1920. This will require 88,230,000 tons of ores, a quantity which cannot be supplied from the existing home deposits unless magnetic concentration and briquetting of poor deposits be introduced.

Apart from the unsuccessful experiments with magnetically concentrated pisolitic or bean ores of the Hils formation at Salzgitter, the German products of iron-ore dressing which have been briquetted or agglomerated up to the present are the magnetic iron ore from Breitenbrunn in the Saxon ore mountains, the so-called washed sands (oolitic brown iron ore) at Gross Ilsede (mixed with clay and waste smelting materials), and, in addition, small quantities of fine spathic iron ores at some works in the Siegerland. These are either separated hydraulically from such gangue as quartz, wacke, etc., in a settling machine, or are freed of a large proportion of the other ores of approximately equal specific gravity (zinc blende, copper pyrites, iron pyrites, etc.), and sorted out with the fine spar, by means of a subsequent magnetic concentration. At many works in the Siegerland, however, it is preferred to charge the fine ore, after preliminary roasting, directly into the furnace with the lump ore, in spite of the disadvantages which may arise under certain circumstances.

In Austrian Silesia and Hungary, agglomeration of magnetically concentrated Hungarian spathic iron ore (partly in admixture with flue dust and burnt pyrites) has been carried on to quite an appreciable extent for some years.

In the U.S.A. and Canada the agglomeration of concentrated magnetic and other iron ores (more especially Franklinite) is continually on the increase.

(*c*) **Roasted Ores and Lixiviated Ores.**—The principal materials included under these terms are: the large quantities of smalls obtained in the usual methods for roasting and burning of spathic iron ores; the powdery residues obtained from pyrites burning, the finely divided residuals—known under the general name of "purple ore" on account of their colour—obtained in the lixiviation of burnt pyrites; the fine residues obtained by sieving and roasting the copper schists occurring at Mansfeld; roasted zinc-blendes and other calcined products; and, in addition, such iron-rich materials as aniline mud, etc.

Spathic iron ore is deprived of its moisture and carbon dioxide, and is largely converted into ferroso-ferric oxide (Fe_3O_4) by roasting in a shaft

furnace fired by coal, coke, or gas, when it becomes considerably loosened and concentrated. The resulting material is known as roasted spar.

Iron pyrites (disulphide of iron ($Fe\,S_2$) in the pure state) is generally roasted in gas-fired continuous kilns, when the sulphur is evolved as sulphur dioxide and applied to the manufacture of sulphuric acid, liquid sulphurous acid, or is used in paper making The burnt pyrites consist, for the greatest part, of iron oxide (Fe_2O_3). The pyrites obtained from the beds usually contain copper pyrites ($Cu\,Fe\,S_2$), which cannot be completely removed, even by very extensive dressing. In this case the burnt pyrites are cupreous, and often contain in addition small quantities of other metals, such as silver, gold, and zinc. Above certain minimum contents of copper and other metals it becomes profitable to recover them by lixiviation, precipitation, etc. This chemical treatment is of the utmost value in regard to the further application of the residues as iron ore, since by it the copper and residual sulphur, which would have a detrimental effect on the iron, are reduced to minute quantities, and the purple ore becomes infinitely more valuable

Thus, for example, the residues from the Rammelsberg pyrites of Oker, Harz, and the burnt pyrites obtained from Rio Tinto, Spain, are purchased and worked up by various German and Austrian ironworks (Konigshutte, Witkowitz, and so on), while the residues of the pyrites exported from Sulitjelma (Norway) are worked up for silver and copper at the Helsingborg Smelting Works (Sweden).

The coarsely powdered roasted spathic ore and the finely divided moist burnt pyrites or purple ore (usually resulting from lixiviation) are much less suitable than rough or dressed ores for direct smelting. While, however, briquetting of fine roasted spathic ore is only carried out at a few places, and then only on an experimental scale, the agglomeration of purple ore, both by itself and in admixture with other materials, has found increasing application in the last few years, and has, in fact, been developed on a commercial scale

The Mansfeld fine residues mentioned above have been subjected to a simple process of briquetting at the works of the Mansfeld Copper Schist Treatment Co.[1] for some years.

The cupriferous schist is first thrown on to shaking sieves in order to separate particles of shale from the so called coarse and fine residues, since the presence of fines hinders calcination during the heap burning, and has a detrimental effect on the output and coke consumption in the subsequent smelting. After the shaly schists and coarse fines have been calcined with faggots in open heaps in order to remove bituminous matter, the shale is raked away from the burnt fines, which are then sieved, mixed with the fines obtained from the preliminary sieving, and briquetted.

[1] See "Die Mansfeldsche Kupferschiefer bauende Gewerkschaft," *Festschrift zum X deutschen Bergmannstage*, 1907, pp. 119 120.

2. Metallurgical Products.

These consist mainly of the coarsely divided waste products obtained in considerable quantities during the working of smelting furnaces, such as converter dust and flue dust from iron blast furnaces and other metallurgical operations. Generally speaking, all such materials contain sufficient metal to make briquetting and subsequent metallurgical treatment a paying proposition. In addition, roll cinder from iron and steel rolling mills, the iron rich residues (iron granules) obtained during the grinding of basic slag, zinciferous slags from zinc smelting, and other similar metallurgical waste products, must also be taken into account under this heading.

(*a*) **Flue Dust.** The gases issuing from the throat of a blast furnace are charged with dust, and are passed through series of alternately horizontal, descending and ascending pipes of large diameter provided with cylindrical or hopper shaped downcomers, in which the dust settles and forms flue dust. Of course the heaviest particles settle close to the furnace, while the remainder settle at more remote distances, according to their lightness and fineness. If the gases are to be turned to profitable account, this dust separation is essential, and if it is intended to use them for driving gas engines, a further and more complete purification must be resorted to.

The composition and quantity of flue dust is governed by the nature of the ores, additions, and fuels charged into the furnace, and by the prevailing burden and working of the furnace. They are also dependent on the pressure of the hot blast, which is, in turn, determined by the height and output of the furnace, and also by the state of the weather. Consequently the composition of flue dust is found to vary very considerably from works to works.

The heavier flue dusts generally consist largely of fine grained and powdered particles of ore in its original or completely altered form, and of particles of additions which have probably been applied to produce lime, magnesia, alumina, or siliceous materials. Such additions either increase the quantity, or produce a marked alteration in the melting point, of the slag. The flue dust also contains quite considerable quantities of coke dust and moisture. The table below contains analyses of flue dusts of various origins :—

	Flue Dust from the Gewerkschaft Deutscher Kaiser, Bruckhausen a. Rhein.	Flue Dust from Friedenshutte O.S.
	per cent.	per cent.
Silica	11 41	13 60
Alumina	6 86	6·10
Iron	37 51	25·00
Manganese	2 16	1·10
Phosphorus	0 73	0·26
Lime	7 91	3 50
Magnesia	2 02	2·00
Coke dust (loss on ignition)	11·86	31 80
Copper	0 023	0 023
Lead	0 06	1 20
Sulphur	0·267	1 00
Zinc	traces	3 50
Arsenic	traces	
Alkalies	residue	?

In these flue dusts the iron content amounts to 37·51 and 25·00 per cent., in other dusts (from the Revier district) as much as 45 per cent. has been found. Poor dusts can be concentrated magnetically.

The quantity carried away naturally increases with the quantity contained in the charge, with the quantity produced in the blast furnace by the breaking up of large pieces as a result of mechanical and chemical action, and also with the blast pressure The largest quantities are produced during the working up of the chalky Minette in the large furnaces of Lorraine and Luxembourg, since this soft and friable iron ore not only produces large quantities of smalls, but is also rapidly broken down by the action of heat and moisture in the shaft of the furnace

Medium-sized blast-furnace plants, working on Minette ore alone, yield 70 to 100 tons of flue dust per day from the first chamber or downcomer, while large works obtain as much as 180 tons per day.

Even with blast furnaces running mainly on ores of different origin yielding considerably less quantities of dust, the amount of iron-rich flue dust produced day by day is so great, that considerable losses would ensue if it were not turned to some account.

In 95 plants in the German Empire alone which produced 10,833,000 tons of pig iron in the year 1909, about 1,500,000 tons of flue dust are obtained each year of 300 working days, assuming a daily recovery of about 50 tons per day from each plant. With an average iron content of 35 per cent., this corresponds to 525,000 tons of pig iron.

At the prevailing market prices of 30 pfennige for each per cent. Fe

55 pfennige for each per cent. Mn, and 10 pfennige for each per cent. of residue (considered as addition), the value of a flue dust containing 35 per cent. Fe, 2 per cent. Mn, and 20 per cent. residue would amount to 10·5 + 1·10 + 2·00 = 13·60 marks per ton when converted into briquettes suitable for smelting. In this case, the annual production of 1,500,000 tons of flue dust corresponds to a money value of 20,400,000 marks.

This great value is, however, only utilised to a very slight extent.

Up to the present time, by far the greater part of the flue dust obtained both in and out of Germany has been regarded as an intolerable nuisance, and is usually consigned to the tip. Only at a limited number of works is a small proportion converted into lumps and re-charged into the blast furnace. This is not altogether due to lack of effort and experiment, for such endeavours have been carried on with commendable industry during the last few years, but is largely owing to the special difficulties presented by the briquetting of flue dust, particularly as each different composition requires a special treatment.

As a result of this knowledge and of continued experiments—many of which have led to satisfactory results in recent times—it appears probable that before very long the conversion of iron-rich flue dust into briquettes will become fairly general.

It is by no means necessary to briquette the flue dust by itself; in many cases it is much more suitable to mix the dust with other, and preferably heavier, materials, such as ores, burnt pyrites, which, among other things, increase the weight of the individual bricks and diminish the costs per ton of briquettes.

(*b*) **Converter Dust.**—The hot gases and vapours issuing from the mouths of the converters in which Bessemer steel is blown by the acid (Bessemer) process or Thomas steel by the basic process, carry with them large numbers of molten particles. Such as do not burn fall to the ground in the immediate vicinity of the converter, and when cold form the so-called converter dust. This is a valuable iron-rich waste product which, like flue dust, can be rendered useful by briquetting, preferably after admixture with other suitable materials. This is already carried out at Friedenshütte O.S., among other places.

(*c*) **Roll Cinder** (*Roll Slag*).—This is made up of the scaly particles of magnetic oxide of iron detached from the surfaces of red-hot iron and steel ingots and rolled material (rods, rails, beams, angle iron, sheets, bars, etc.) during hammering and rolling, and known as Hammer

scale and Roll cinder. If it is not self-detached, it is removed by means of besoms, particularly in plate rolling. The not inconsiderable quantities of roll cinder obtained in large rolling mills is of considerable importance in briquetting.

Such material has already been successfully briquetted with other materials, such as finely divided ores, etc., at the Ilseder Hutte, where the roll cinder from the Peiner Rolling Mills is dealt with.

(*d*) **Iron-rich Basic Slag Residues.** The large quantities of slag obtained in the basic Thomas-Martin process at iron and steel works is broken up and finely crushed on account of the lime and phosphoric acid content, which allows it to be sold at a good price as a manure. Before the fine grinding the iron-rich constituents of the slag are sorted out by sieving, and the iron granules obtained are quite adapted to briquetting after admixture with other materials.

(*e*) **Metallic Flue Dust.**—This principally includes the metal-rich flue dust obtained during smelting operations in metallurgical works, more particularly in lead and silver works. The stream of gas from the smelting furnace is almost invariably passed through a series of chambers (dust catchers) before being passed to the chimney. In the cupboards the greater proportion of the metals or metallic oxides contained in the gases in the form of dust or vapour is deposited.

At some of the lead and silver works in Harz and Mansfeld such deposits have for some years been converted into briquettes, either alone or in admixture with other materials, and charged into the smelting oven.

(*f*) **Cement Copper** from copper extraction.

(*g*) **Zinc Slags.**—Slags from the smelting of zinc can be brought into a form suitable for re-smelting by crushing and briquetting with suitable binding materials, such as tar pitch, etc., a method which has recently been put into operation at Oker, Harz.

In addition to the waste products of iron and other metal smelting mentioned above, other materials are sometimes obtained, adaptable to briquetting under certain conditions.

3. Metal Swarf.

Large quantities of filings, drillings, planings, etc., are obtained daily in engineering workshops and foundries during the working up of castings, forgings, rolled bars, and other objects of iron, steel, and other metals and alloys. Such scrap materials have always been utilised by re-melting, or have been sold for the same purpose. This

method of recovery is, however, incomplete, on account of the considerable losses by oxidation and "slagging off" during the process.

Such losses can be largely prevented by compressing the swarf into strong dense masses by some suitable briquetting method applied prior to re-melting. Metallic briquettes, whose fusion presents several other advantages, have already been prepared from finely divided swarf of cast iron, steel, wrought iron, mild steel, aluminium, copper, bronze, brass, white metal, and similar alloys. There are at the present time various large works (Sachsische Maschinenfabriken von Rich. Hartmann, Chemnitz, A. Borsig Berlin-Tegel, etc.) who sort out their waste metals, free them from dust and other foreign constituents and compress them into briquettes, which are then melted. Again, central briquetting plants have been in existence (Budapest and Chemnitz) for several years, or are in course of construction (in Berlin, Vienna, and Leeds), for dealing with all classes of metallic waste brought from the various engineering shops of the town and compressed into briquettes. This arrangement is one that appears to recommend itself to other large centres of iron and metal industries.

B. GROUNDS FOR, AND OBJECTS OF THE BRIQUETTING OF ORES, ETC.

The principles and objects governing and leading up to the briquetting of ores and other metallic materials at the present time, and offering prospects of considerable advancement in the near future, are partly obvious from the preceding remarks, but require still more complete description.

Briefly, the grounds for briquetting are somewhat as follows:—

(*a*) The greatly increased need and consumption of iron ores as compared with earlier times, the necessity for carrying large quantities, often from remote places, by land, canal, or sea, increasing deliveries, and the incidental production of fine ores by dressing, repeated loading and unloading, protracted journeys by rail or sea, and long storage, introduction of fine burnt pyrites (purple ore), etc., for the production of iron.

(*b*) Difficulties in the smelting of fine iron ores in the existing large scale operations, and the necessity of solving these difficulties as far as possible.

(*c*) The desire to turn to account the considerable quantities of iron-rich flue dust and other waste products of iron smelting.

(*d*) The attempts to utilise, or turn to better account, waste products containing metal from other smelting operations, more especially lead, silver, and zinc smelting

(*e*) The desire to use again the quantities of fine or coarse waste obtained in machining iron and other metals without loss of metal, or, at least to permit of its being sold at scrap prices.

(*f*) The great development in the briquetting of small coal and other waste fuels, and in the production of artificial stones during the past ten years, the experiences collected in this way, the evolution of suitable methods, presses, and other working appliances, all of which appear to be more or less applicable to the new objects.

Some further explanations must be given with regard to the factors enumerated under (*a*) and (*b*). Increasing production of fine ores and the difficulties involved in their smelting on the large scale under prevailing conditions:[1]—In the blast furnace lumpy as well as fine ores have always been smelted. In olden times, when the furnaces were only very low, the charge was blown at relatively low blast pressures, the top of the furnace was uncovered, and the waste gases only used for blast heating and steam production. This made the smelting of a certain proportion of fine ore a comparatively easy matter.

In Upper Silesia, for example, even the fine dusty brown iron ores, which occur there almost exclusively, are smelted, although they fall completely to powder after drying and removing the water of hydration. It is quite sufficient to loosen the charge by the addition of limestone and fuel in lumps.

With the modern increase in height and output of the blast furnace, the increase of blast pressure, and the use of the waste gases in gas engines, the evils arising from the use of ore dust have also largely increased.

So long as there was a sufficiency of lump ore, dust was kept out of the operation as far as possible. In recent times, however, this state of affairs has considerably altered. As a result of accelerated mining operations, and the destructive action of dynamite and other powerful explosives, a considerable quantity of fines are obtained in addition to the lumps of ore. The length of transport, whether by sea or rail, further increases the attrition of iron ores. Again, iron-rich ores are becoming scarcer and scarcer, and it has become necessary to concentrate the poor ores, preferably by magnetic concentration. This

[1] H. Wedding, "Die Brikettierung der Eisenerze und die Prufung der Erzziegel," *Stahl und Eisen*, 1906, p. 2 *et seq.*

cannot be carried out effectively without thorough pulverising. To such fine ores must be added, among others, the powdery lixiviated burnt pyrites, which are now being more extensively applied in the production of iron.

During regular running of the blast furnace, moderate quantities of fine ores can be charged along with the coarse ores. The quantity must seldom exceed 11 per cent., and even then there arise numerous difficulties; *e.g.*

Rapid rolling of the fines, giving rise to slagging before reduction has taken place. Fritting together of the lumps by fusion of the fines, giving rise to hanging and falling of the charge, which seriously interrupt the furnace operations.

Removal of particles of ore in the gases issuing from the shaft, increasing the quantity of flue dust, which is however, still a product of value and decreasing the output of iron.

These difficulties and disadvantages, in combination with the necessity of dealing with fine ores in increasing quantities, formed the most powerful motives for the efforts to convert them into lump form.

From the principles laid down above, it appears that the following are the principal objects of briquetting or agglomerating iron ores, etc.:—

(*a*) Artificial production of good, smeltable lumps of ore from fine ores, burnt pyrites, and heavy flue dust under conditions which permit of providing for or diminishing detrimental impurities, especially sulphur.

(*b*) Introduction and maintenance of a regulated and uninterrupted furnace running.

(*c*) Increase in the charge of ore and the output of iron.

(*d*) Diminution of the coke used, and the development of flue dust.

(*e*) Reduction of, or at least not increasing, the costs of production of the crude iron.

C. REQUIREMENTS OF GOOD IRON ORE OR FLUE DUST BRIQUETTES OR AGGLOMERATES. BRIQUETTE TESTING.[1]

In order that the above-mentioned objects can be really effected, the briquettes (or agglomerates) must, in general, possess the following characteristics:—

[1] Partly after H. Wedding in *Stahl und Eisen*, 1906, p. 2 *et seq.*

1. They must be able to withstand open storage without being destroyed by damp, the heat of the sun, or by frost.

2. They must be strong and dense, but at the same time be porous enough to permit of the penetration of the gases right into their interior during smelting. They must not, therefore, have a fused crust.

3. They must be able to resist the action of steam heated to 150° C.

4. They must hold together until reduction is quite or nearly complete and fusion has commenced, *i.e.* up to a temperature of 600–1000° C., even under the action of a stream of gas consisting of a mixture of carbon monoxide and carbon dioxide.

5. The additions, which have possibly been used in briquetting, must not have any detrimental effect, neither on the iron to be smelted nor the lining of the furnace, and must not, therefore, contain any appreciable amounts of sulphur or alkalies.

6. The costs of production, and consequently price, of the briquettes or agglomerates must not be higher than lump ores of the same quality.

Little importance can be attached to a uniform and geometrical shape of the blocks, since irregular shaped agglomerates fulfil the same purposes in the blast furnaces as pressed blocks

Requirements 2 to 4 are tested for somewhat as follows

2. The strength of the bricks can be tested in a rough fashion, which is, however, ample for all practical purposes, by allowing them to fall freely from a height of 2 to 4 metres on to a stone floor. If the briquette merely falls to pieces without yielding any appreciable amount of dust it can be regarded as of ample strength for charging into the blast furnace, *i.e.* the briquette is strong enough not to be crushed to a powder during the fall on to the top of the charge in the furnace and by the subsequent impact of the masses of ore, briquettes, etc., charged in. At the same time it is a measure of the compliance of the briquettes with conditions 3 and 4.

A pressure testing press is required for an accurate determination of the compressive strength of the briquettes in the cold or hot condition. A press which is well adapted for this purpose is illustrated and described below.

Hydraulic Testing Press by Bruck, Kretschel and Co. (fig. 1).

This small press, built by Bruck, Kretschel and Co. of Osnabrück, is worked by means of oil, and, as illustrated, is hand operated, but mechanically operated models can be supplied to order. Its con-

struction, operation, etc., is made clear from fig. 1 and the description given below.

After the parts removed from the main body of the press for the purpose of despatch have been re-assembled according to fig. 1, and the second

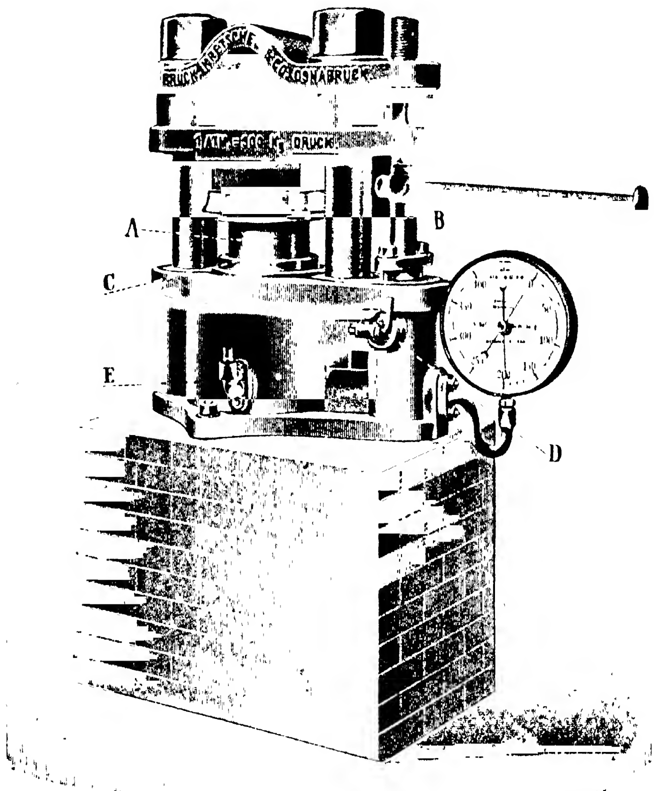

FIG. 1.—Hydraulic Testing Press, by Bruck, Kretschel & Co.

manometer attached at E, the following measures are to be taken in order to fill the press with oil:

(1) The clamping screw of the ring C clamping the large piston A is loosened, and the cock of the small oil cup D is opened so that air can escape while the piston sinks to its lowest point. The manometer taps must be closed previously.

(2) At the same time the small piston B is screwed down to its lowest position, so that both pistons A and B are in their lowest positions.

(3) After the tap D is placed so that its handle is horizontal and points

to the piston B, when the oil cup is in communication with B, pure mineral oil of medium viscosity is poured into the cup and the piston screwed to the top of its stroke. Oil is constantly poured into the cup in such a way that no air enters the tap until the piston is at the top of its stroke.

(4) The tap D is then closed and the piston B screwed to the bottom of its stroke, when the large piston A is elevated slightly.

(5) The screw of the clamping ring C, which rests on the lower cylinder, is screwed up tight to ensure that the piston A does not fall again

(6) The tap D is again opened, oil is poured into the cup, and the small piston B again turned to the top of its stroke, exactly as described under (3)

(7) Directions 4, 5, and 6 are then repeated in order, and the large piston elevated until the distance between it and the cross head is such that there is only 1 mm play for the whole or fragment of a briquette when the small piston is at the top of its stroke. The press is now ready for operation, and the block is compressed by screwing down the small piston until on opening the manometers the desired pressure is indicated

(8) After the press has once been filled in this way, it is only necessary to add fresh oil from time to time to replace the small amount lost by leakage through the stuffing box of the large piston In order to diminish this as much as possible, it is necessary to screw up the clamping screw and ring C as tight as possible when the press is out of operation, so that the weight of the large piston does not unnecessarily load the oil and cause it to flow through the parts which are not quite oil tight

Further, it is advisable to use only one manometer during ordinary operations, and to use the other only for purposes of control.

(9) In case the collar is completely tight, it is possible that air has accumulated under the stuffing box during charging with oil This can be removed by means of a screw provided above the column E.

(10) Presses which completely crush the briquette are provided with a block of cast iron to act as a support.

If such a press is to be used for testing two halves of a briquette cemented one on top of the other, it is only necessary to remove the cast iron plate, when the oil need not be interfered with.

A testing press of this type, but provided with a belt and pulley drive from the transmission shaft of an electric motor, is installed in the Kgl. Bergakademie at Berlin (Preparation Laboratory), and has given quite good results in a large number of tests.

The degree of penetration for reducing gases depends on the porosity of the brick. A suitable measure of porosity is the amount of water which can be absorbed, expressed in volumes per cent. of the briquette. For example, an ore briquette of 20 per cent. porosity can take up one-fifth of its volume of water. It is only necessary, therefore, to determine the cubical contents of a briquette, and to drop water on it

from a graduated burette until saturated. From the volume of water absorbed, it is quite a simple matter to calculate the porosity. A good porosity is recognised by the fact that the briquette sucks up the water rapidly.

Another method of testing consists in weighing the briquette, allowing it to stand in water until saturated and then re-weighing. From the increase in weight the porosity can be calculated in terms of percentage by weight, but this does not permit of the comparison of briquettes of different specific gravities.

3. The influence of steam at 150° C. is determined by submitting the briquette to the action of steam at a pressure of 4 atmospheres above the ordinary pressure (corresponding to the temperature required) in a suitable closed vessel for a pre-determined time. Under this treatment the briquettes should not fall to pieces.

The test for resistance to the action of steam can also be combined with the following:

4. In order to test the power of holding together at temperatures of 600° to 1000° C. H. Wedding uses a muffle in which the briquette is placed and heated to a temperature of 800° C. by means of gas.

Wedding uses such a muffle at the School of Mines in Berlin. The briquette is placed in the muffle and tested for strength by means of a small press, whose plates are heated to 800° C. by means of gas flame. In this way it can be shown that while some briquettes lose strength on heating, others become stronger.

Wedding proposed to construct a testing apparatus (sketched by him in *Stahl und Eisen*, 1906, p. 76) into whose cylinder steam at 150° C. is admitted, and then carbon monoxide and carbon dioxide are introduced with simultaneous increase of pressure.

5. At the Ilseder Works the briquettes to be tested are placed in the firing hole of a boiler heated with blast-furnace gases and maintained at a temperature of 1000°–1100° C. for a long time.

6. On economical grounds the costs of briquetting or agglomeration must be as low as possible, and generally should not exceed the difference in price between fine and coarse ores (usually 3 to 4 marks); in no case must they exceed the price of lump ores of equal quality. Consideration must be given to the fact that good briquettes are often of greater value than lumps of the same kind of ore, and can therefore, under certain circumstances, demand a correspondingly higher price.

Briquette Testing Institution.—Wedding[1] advised the establish-

[1] *Verhandl. des Vereins z. Beförd. d. Gewerbfleisses*, Berlin, 1907, p. 210.

ment of a testing laboratory for ore briquettes, preferably in Central Germany, where systematic experiments of general interest could be undertaken on the applicability of the various methods for the briquetting of iron ores. The necessary means should be provided jointly by the State and private industry. It is also recommended that the work of the institution should include the testing of methods and appliances for the magnetic concentration of poor iron ores.

This proposal caused the "Ore Briquetting Commission" instituted some years previously by the "Vereins deutscher Eisenhuttenleute," to send a circular letter to the whole of the German ironmasters, with the object of determining if there were sufficient interest in such a project, and to what extent the institution would be used. The result of the circular was, however, that the Commission resolved at their meeting on 7th December 1907 that "the question of the establishment of a testing institution be referred back for the present." Since that time no other conclusion has been arrived at up to the present, and it is left to the discoverers and works management of blast furnaces to carry out their own testing of briquettes and briquetting methods in any manner which commends itself to them.

Experiments in Blast Furnaces. No matter how satisfactory the tests carried out in briquette testing laboratories appear to be, they should always be confirmed and exemplified by actual tests carried out in working blast furnaces.

But such experiments in which small quantities of briquettes are added to the ores, cannot give conclusive evidence as to the quality and uses of briquettes. For this purpose it is necessary to add at least 50 per cent. of briquettes. The most positive evidence can only be obtained by running parallel furnaces, one on briquettes alone and the other on similar ores without briquettes, as proposed by Dr A. Weisskopf.[1] Careful determination of the results of working of the two furnaces, and consideration of the briquetting costs, then indicate exactly the economical and other advantages gained.

The author does not know if such experiments have been carried out on the large scale. In the majority of cases it has been thought sufficient to use greater or lesser additions of briquettes instead of ores. In the description of the various methods of briquetting given in Section II., the results of experiments and actual working are described so far as they are accessible.

[1] *Stahl und Eisen*, 1908, No. 3, p. 99.

Bengal

SECTION II

VARIOUS METALLURGICAL AND SMELTING BRIQUETTES AND AGGLOMERATES.

FIGS. 2 to 7 are reproductions from photographs of a number of ore, flue dust and metal briquettes and agglomerates of various shapes, dimensions, weights, etc. As already pointed out on p. 11, the shape of the briquettes is of relatively little importance from the point of view of smelting or melting. At the same time it must not be forgotten that stones with sharp corners and edges are liable to yield unwelcome quantities of fine ore by crumbling and attrition, especially if the briquettes are only moderately strong. From this point of view, therefore, round shapes with as few edges as possible are the most desirable.

Ball briquettes are not produced on account of special difficulties in pressing, but fig. 6 (p. 25) illustrates at 1, three egg briquettes of finely crushed zinc slag and pitch, prepared in a roll press and showing the rolling lines quite distinctly. Up to the present the egg form has not been adopted for non-ore briquettes in spite of their recognised suitability.[1] The egg shape is only applicable to certain methods of briquetting.

Cylindrical shapes can, however, easily be produced for all kinds of metallurgical briquettes. The flue dust briquette, No. 5, fig. 7, is a simple cylinder, while the briquettes in fig. 4 (1) (flue dust), fig. 3 (11 and 12) (cast iron and steel swarf), and in fig. 5 (1–5) (iron and other metal swarf) are cylindrical, with slightly coned edges.

The truncated, steep conical type of briquette is illustrated in fig. 2 (3 and 4).

The cubical briquettes with rounded vertical edges shown in fig. 3

[1] *Stahl und Eisen*, 1908, No. 3, p. 98. Even before this date L. Marton had strongly recommended the egg shape for his process of briquetting.

(7, 5, 4, and 9) form a transition stage to the plane-sided, cubical briquettes.

These briquettes are similar to the disc-shaped flat cubes with rounded short edges as shown in fig. 3 (6) (burnt pyrites) and (10) (wrought-iron drillings). The small experimental samples, 5 to 8 in fig. 2, are also cubical in shape. Brick-shaped briquettes of more

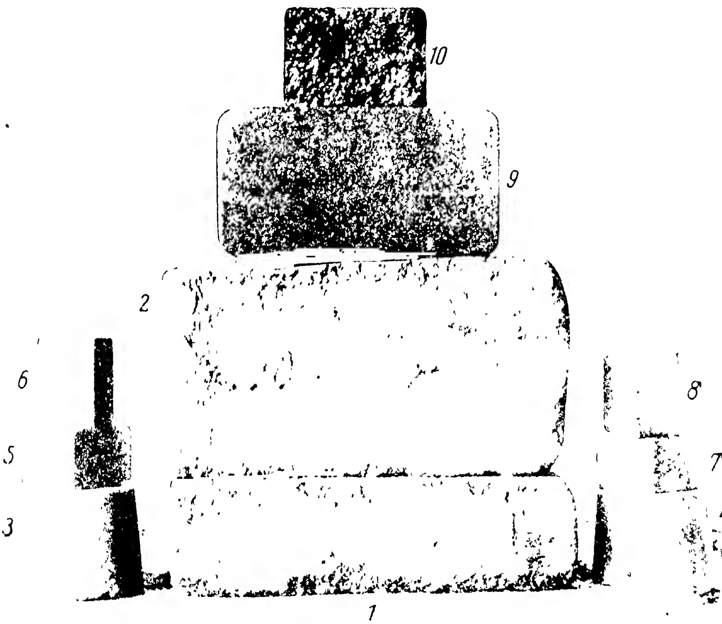

FIG. 2. Various old briquettes: purple ore (1, 2, 5, 7), brown iron ore (4), flue dust (6, 8, 9, 10).
(From the Kgl. Bergakademie in Berlin.)

elongated or quadratic shape are illustrated in fig. 2 (1, 2, 9, and 10), in fig. 3 (1 and 2), and in fig. 4 (1, 2, and 3).

The ordinary elongated brick shape is met with in Germany, while the quadratic shape is customary in Sweden.

Generally speaking, the brick shape is only suitable for ore or flue-dust briquettes of great strength on the grounds enumerated above. It is quite immaterial whether the strength is attained immediately after pressing, by any subsequent process, or by exposure to the air. The brick shape is very convenient from the point of subsequent treatment or storage, since the briquettes permit of easy stacking in waggons or on the store ground.

In addition to the shapes illustrated, others are also made *e.g.* column shape with the top and bottom edges rounded off, and briquettes

with depressions in the top and bottom to facilitate ventilation during pressing (Rónay system).

With regard to the size of the briquettes the dimensions of lumps of ore are usually exceeded, since larger blocks are produced with

greater advantage and are more resistant, a factor which is of importance with soft material On the other hand, ease of handling must be considered, more especially when the briquettes have to be moved

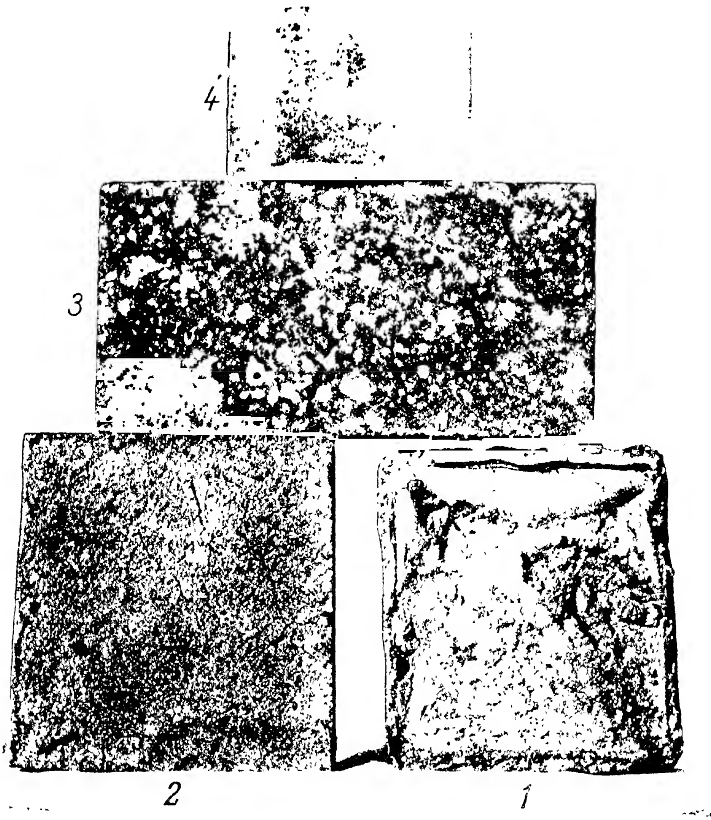

Fig. 1 — Sintered briquettes of magnetic iron ore (1) and purple ore (2) prepared by the Gröndal method. Purple ore briquette (3) made by Schumacher's quartz meal-lime method Flue dust briquette (4) made by L. Weiss's lime-carbonic acid method

(From the Kgl Bergakademie, Berlin)

about by hand This is determined by the weight of the individual blocks

Elongated brick-shaped blocks are seldom larger than ordinary building bricks (250 × 125 × 65 mm).

During charging into the shaft of the blast furnace many of the long bricks break into several pieces. This is of advantage rather

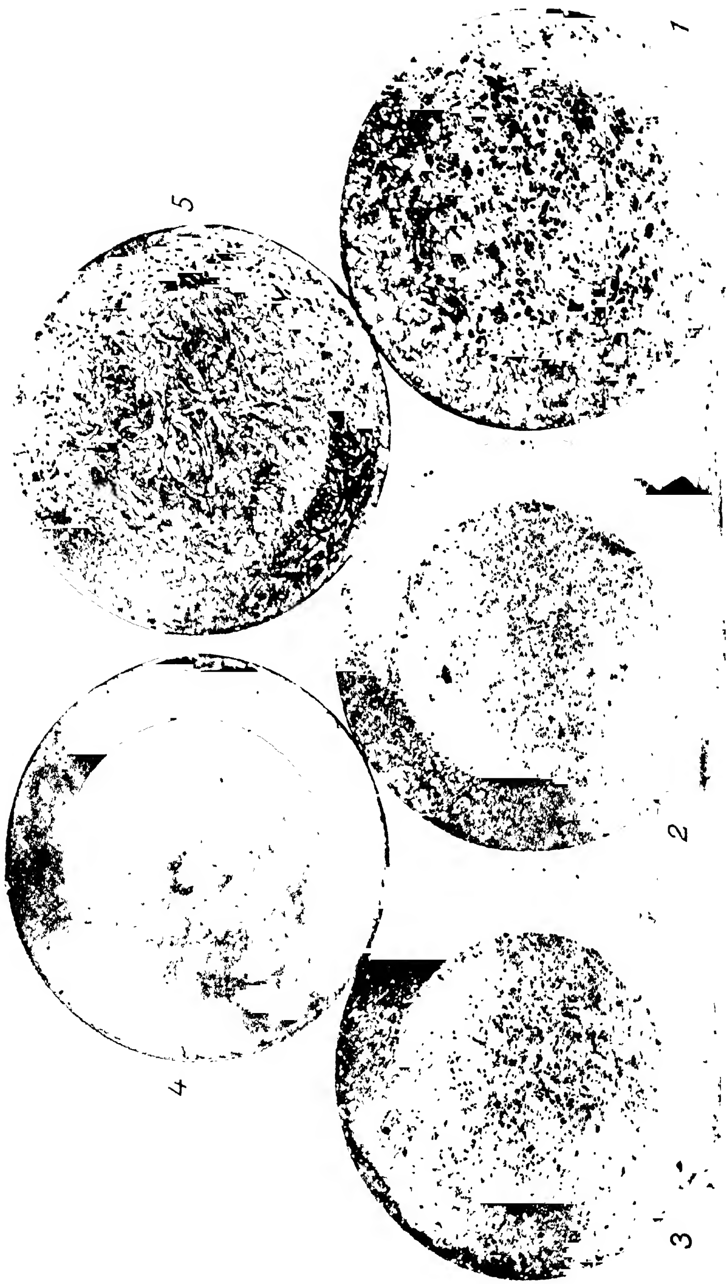

FIG. 5.—Briquettes L. Weiss' of swarf from wrought iron 1, [illegible] 2, [illegible] 4 and copper 5.
(From the Kgl Bergakademie, Berlin.)

than detriment from the point of view of the reduction, so long as the individual pieces still correspond to the requirements enumerated. The weight of the briquette = cubical contents × specific gravity (or density). The specific gravity is determined by the kind of material or the briquetting mixture, as well as by the strength of the compression and by the physical and chemical effects of any possible subsequent treatment. Generally speaking, the briquetting costs per ton decrease with increasing specific gravity of the briquettes, except when the attainment of a high density entails heavy expenditure. Nowadays a minimum density of 1·4 to 2·1 is aimed at in the briquetting of flue dust, by admixture of heavy ores and burnt pyrites.

The principal dimensions and weights of the briquettes illustrated in figs. 2 to 7 are given in the following table.

Fig. No.	No. in Fig.	Raw Material from which the Briquette is made	Principal Dimensions	Weight
			mms.	kgs.
2	1 & 2	Purple ore (with flue dust)	225 × 125 × 65	4·5
2	3	Flue dust (with lime)	aver. diam. 70, thickness 60	0·45
2	4	Iron ore (with lime)	,, 70, ,, 55	0·50
2	5	Purple ore (with quartzitol cement)	50 × 50 × 32	0·25
2	6	Flue dust	50 × 50 × 32	0·15
2	7	Flue dust and coke (with pitch)	170 × 85 × 65	1·4
3	1	Giessen manganese ore (with 5 per cent. chalk, steam hardened)	220 × 130 × 75	5·35
3	2	Flue dust (with 1 per cent. $MgCl_2$)	220 × 130 × 75	4·75
3	4		105 × 105 × 85	1·82
3	5	O.S. brown ironstone	105 × 105 × 90	2·00
3	6	Purple ore	105 × 105 × 50	1·25
3	7	Flue dust	105 × 105 × 85	2·20
3	9	Cast iron swarf	105 × 105 × 85	5·15
3	10	Wrought iron swarf	105 × 105 × 40	2·22
3	11	Cast iron swarf	diam. 125, thickness 90	5·55
3	12	Steel swarf	,, 125, ,, 80	5·33
4	1	Magnetic iron ore (sintered)	145 × 145 × 70	1·71
4	2	Purple ore (sintered)	160 × 150 × 80	2·10
4	3	Purple ore (with lime, quartz meal, steam hardened)	250 × 125 × 65	4·2
4	4	Flue dust	diam. 125, thickness 85	2·7
5	1	Wrought iron swarf	,, 125, ,, 40	2·5
5	2	Cast iron swarf	,, 125, ,, 35	4·4
5	3	Bronze swarf	,, 125, ,, 25	1·7
5	4	White metal swarf	,, 125, ,, 15	1·5
5	5	Copper swarf	,, 125, ,, 15	1·1
6	1	Zinc slags (with tar-pitch)	100 × 60	0·11
7	5	Flue dust (with cell pitch)	diam. 140, height 100	3·35

NOTE.—The briquettes of fig. 3 (4 to 7, 9 to 12) are simply highly compressed, those of fig. 4 (4) and fig. 5 (1 to 5) are compressed after moistening the swarf with lime water.

The heaviest of the briquettes dealt with here are upwards of 5·5 kgs. At many works, however, still heavier blocks are produced, *e.g.*

FIG. 6.—Egg briquettes of zinc [illegible] Various [illegible] fine spar [illegible]
(From the K[illegible])

at the Friedrich-Wilhelmshutte at Sieg, cylindrical stones of 180 mm. diameter and 130 mm. height, weighing about 7 kgs., are compressed during the working up of Siegland roasted spar At the Friedenshutte O.S., briquettes weighing up to 7 kgs. are prepared.

The superficial appearance of the briquettes is seen from figs 2 to 7 to be partly smooth, and even bright in a number of stones, while others are rough, according to the nature of the material briquetted, the pressure applied, and the kind of subsequent treatment which may be applied. A rough, porous surface is the most favourable to penetration by the reducing gases in the blast furnace

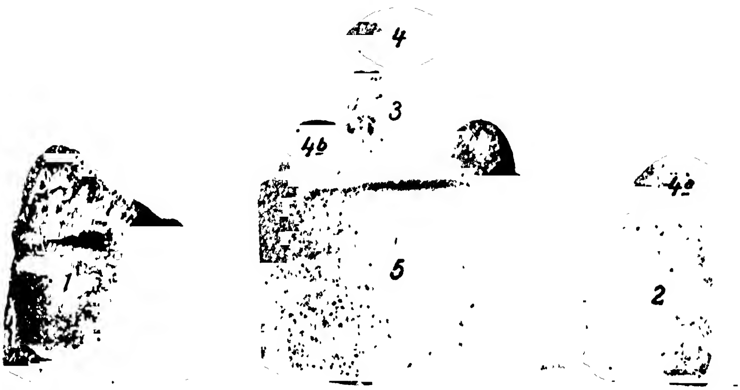

FIG. 7. Cell pitch (1), and various cell-pitch briquettes of coal and anthracite (2–4b) and of flue dust (5)

(From the Briquette Collection in the Kgl Bergakademie Berlin.)

The structure of the briquettes is invariably finely granular (compare the broken pieces of various ore and flue-dust briquettes shown in fig. 1 (10) and fig. 3 (3 and 8), with the exception of metal-swarf briquettes, which show a coarse, curly, or jagged appearance according to the size and shape of the filings, drillings, or planings pressed together).

The chemical composition of the briquettes corresponds to that of the constituent raw materials, the ratio in which they are mixed together, and to the subsequent treatment. The principal results of analyses of some briquettes produced by the scoriation process[1] are given below:—

[1] According to *Z. Berg- u. Huttenm. Rundschau*, 1906, No 14, p 184.

	I	II	III	IV
	Gellivara Ore	Flue Dust and Purple Ore	Burnt Pyrites	Flue Dust
	per cent	per cent	per cent	per cent
Fe	55·40	44·1[illegible]	49·0[illegible]	43·75
Fe_2O_3	79·2[illegible]	6[illegible]·[illegible]0	70·10	62·50
CaO	6·22	7·52	7·20	11·18
SiO_2	8·91	20·18	9·52	9·4[illegible]

Further analyses will be found in later sections on the various methods of briquetting and plants.

The agglomerates of various compositions and origins illustrated consist partly of rounded and partly of irregular shaped lumps up to 75 mm. diameter and a maximum weight of 250 grms. Further information with regard to these types will be given in the last section as a conclusion to the chapter on complete agglomeration plants and their methods of operation.

SECTION III.

METHODS OF BRIQUETTING AND AGGLOMERATION.

A. GENERAL SURVEY.

THERE are already a number of methods of briquetting, etc., especially for iron ores, burnt pyrites, and flue dust, which differ from each other in a greater or lesser degree. Only a very limited number, however, have passed the experimental stage and have been applied on a manufacturing scale, and only a few methods have up to the present found extended application. This is due principally (as already pointed out in Section I.) to the very varied nature of the materials to be dealt with, especially in the case of flue dust, to the rigid requirements, and last, but not least, to the question of costs (p. 17).

First, a general review of the whole of the known methods of briquetting (brick-making and agglomeration) of iron ores, etc., will be given, taking as a basis a bibliography given by A. Weisskopf in 1903,[1] and since added to by H. Wedding in 1906,[2] and G. Franke in 1909, and altered in places.

In the first place, the classification depends upon whether the briquetting is carried on with or without binding material, and whether, in the latter case, the bond is of inorganic or organic origin. Further, the processes are distinguished according as they are carried out: by simple hand kneading, or in a press with moderate, high, or very high compression at ordinary or elevated temperatures; whether, under certain conditions, the pressed blocks are sintered, or whether the unpressed fine ores are sintered or fused together (agglomeration).

Naturally, many combinations of these processes are possible,

[1] From a Report by A. Weisskopf to the Allgem. Bergmannstage in Vienna, 1903.

[2] *Stahl und Eisen*, 1906, No. 1, p. 3 *et seq.*

especially according as the compression takes place in the cold or hot condition, and as heating is applied before or after the pressing. In addition, there are numerous intermediate processes belonging partly to one and partly to another group. A large number of discoverers have protected by patents many doubtful combinations.

METHODS OF BRIQUETTING AND AGGLOMERATION FOR ORES, ESPECIALLY IRON ORES AND FLUE DUST.

I. Briquetting or Agglomeration without Special Binding Materials.

1 Mixing with water —

(a) Simple hand-making			Cornelia mine, for clayey ores	
			Langloan, for purple ores, burnt pyrites	
(b) Compression under moderate pressure			Mansfeld Mining Co., for crude and burnt copper schist residues.	
2 Compression with moderately high or high pressure.			Kertscher Iron Works (for clayey oolitic brown iron ores).	Preheated in a shaft furnace.
	D.R.P.	133,485	Cöln Müsener A.-V.	Reduction of surface
	,,	90,292	Jacobi	Partial reduction
	,,	119,812	Ronay	Subsequently heated with carbonic acid
	,,	154,583	,,	Afterwards heated in a channel furnace
	,,	154,580	Daelen	Pounded up with binding material.
	,,	139,98[illegible]	Butler	Cast with molten iron.
	,,	1[illegible]5,657	Weiss (for ores, metal scrap and salts).	Moistened with dilute magnesium and potassium sulphate solutions.
			Schumacher (1908, for flue dust).	Moistened with $MgCl_2$ solution.
			Schumacher (1908, for flue dust).	Subsequent heating in superheated steam surface ground.
		...	Schumacher (1908, for flue dust).	Superficial grinding, blocks hardened with steam.
3 Gradual compression up to a very high end-pressure.	D.R.P.	158,172	Ronay (for ores and other materials for smelting).	Binding after airing and the production of a plastic state. Subsequent action of carbonic acid when necessary
4 (a). Sintering or fritting after compression.	D.R.P.	113,863	Blezinger	Sintering in revolving furnace.
	,,	111,768	Edison	Sintering in chain furnace.
			Grondal	Sintering in channel furnace.
			Coltness Iron Works	Sintering in ring furnace.
4 (b). Agglomeration without compression.	D.R.P.	156,709	A. G. fur chemische Industrie.	Sintering in revolving furnace.
	,,	159,485	Petersson	Sintering in special step roasting furnace.
			F. Scott	Sintering in a shaft furnace and kneading the sintered mass with toothed rolls.

5. Fusion and agglomeration.			Wedding (1865)	Fusion in reverberatory furnace.
	D.R.P.	47,132	Thau	,,
	,,	49,963	,,	Fusion with fluxes.
	,,	56,672	Stein	Fusion with reducing agents.
	Am. P.	156,152	Ruthenburg	Fusion in electric roll furnace.
	,,	166,160	Galbraith & Stewart	Fusion in electric resistance furnace.
	,,	780,716	Gates	Fusion by means of an arc between two inclined troughs conveying the material.

II. Briquetting with Binding Materials.

A. With Inorganic Materials.

1. With iron ores. (a) With clayey iron ores.	...		Concordiahutte	Lump ores with ferruginous clay water.
	D.R.P.	71,203	Henzel	Burnt pyrites with clayey ores.
	..		Ilseder Hutte	Washery sand, roll cinder, waste from basic slag, flue dust, purple ore with clayey ores or mud.
(b) With brown-iron ores.	D.R.P.	11,913	Kleist	O.S. brown-iron ore.
	,,	69,345	Georgs. Marienhutte	Laming mass
(c) With spathic iron ore, clay band, or black band ore, or manganese carbonate.	.		Schumacher (1908)	Fine ore and milk of lime, steam hardened
(d) With purple ore.	D.R.P.	61,062	Georgs. Marienhutte	Burnt pyrites and flue dust
	.		Langloan	Burnt pyrites and magnetic iron ore.
(e) With flue dust.	D.R.P.	61,062	Georgs. Marienhutte	Flue dust and burnt pyrites.
2. With clay.	..		Concordiahutte (1865).	See II A, 1 (a).
	D.R.P.	71,203	Henzel	See II A, 1 (a).
3. With lime. (a) With calcium carbonate.	..		Lang & Frey (1860)	Ore, limestone, and coke
			Berthier (1830)	Slag, coal dust, and limestone.
	D.R.P.	135,141	Koeniger	Limestone, borax, sulphuric acid.
(b) With burnt limestone (lime).	D.R.P.	485,810	Edison	Burnt limestone and clay.
	...		Wedding	Lime and carbonic acid.
	D.R.P.	78,013	Duisburg Copper Works.	Lime and ashes.
	,,	111,042	Kleber	Lime, blast-furnace slag, hydrochloric acid, and steam
	,,	103,777	,,	Lime, silicates, and steam.
	,,	111,034	,,	Lime, silicate, chloride, and steam.
(c) With slaked lime.	..		Straschitz	Milk of lime.
	D.R.P.	183,108	Weiss	Subsequent treatment with CO_2 under pressure.
			Schumacher (1908), for manganese ores.	Subsequent heating to 100° C.

(d) With plaster of Paris or cement	D.R.P.	117,191	Cramer	Plaster of Paris, lime, Portland cement.
	,,	159,909	Loewenthal	Magnesium chloride and sand (quartzitol cement).
	,,	131,641	Lehmann	Magnesium sulphate and sodium carbonate.
	,,	149,135	Reinke	Lime and cement.
(e) With silicate of lime			Schumacher	Wollastonite from quartz and ground lime. Treatment with steam.
(f) With lime in various forms.			German Briquetting Co.	Formation of a silicate of lime by heating.
4. With slag or water-glass.	D.R.P.	80,728	Thomlinson	Cold blast furnace slag.
	Am. P.	467,361	Stein	Stirring in molten blast-furnace slag.
	D.R.P.	111,042	Kleber	Lime, blast furnace slag, hydrochloric acid steam.
	,,	138,312 and additional patents	Oberschulte (Scoria method).	Granulated blast furnace slag and steam, milk of lime. Steam hardening of the briquettes.
	,,	64,261	Schoechtermann	Basic slag
	,,	82,120	Wust	Water glass
	,,	151,581	Mewes	Water glass and asbestos.
	,,	163,465	Ronse	Water glass and steam.
5. With Kieselguhr, carnallite, and molasses. See II. B. 6	D.R.P.	191,020	Dunkelberg	Sintering the briquettes in a ring furnace.

B. With Organic Binding Materials.

1. With pit or other form of coal.			Minary and Soudry (1865).	Coking with pit coal
			Kerpely (1865)	,, ,, ,, ,,
			Wedding (1866)	Brown coals containing paraffin
	D.R.P.	141,427	Dobbelstein	Fat coal dust.
2. With tar, pitch, asphalt, petroleum (Masut), clotted blood.	D.R.P.	104,699	Landin	Pit coal, tar, or clotted blood.
	,,	147,312	Hufelmann	Pitch with coke (wood charcoal).
			Weissmann (1888)	Coal and pitch.
			Wedding (1890)	Asphalt or Masut with flue dust.
3. With cell pitch	D.R.P.	133,897	Tramer	Lignosulphite salts, cell pitch.
4. With naphthalene, paraffin, molasses	D.R.P.	81,906	Fegan	Naphthalene, paraffin.
	,,	191,020	Dunkelberg	Molasses, Kieselguhr, carnallite (II. A. 5).
5. With resin	D.R.P.	132,097	Edison	Resin soap
6. With starch			Leopold Marton (1905).	Starch paste from maize and weeds. High pressure. (Egg briquettes.)

BRIQUETTING METHODS FOR METAL-SMELTING PRODUCTS, IRON AND METALLIC SWARF.

For Metallurgical Products.

Simple compression	Mansfeld Mining Co.	For lead bearing flue dust.
Binding with slaked lime and burnt pyrites.	Anhalt Silver Works.	For lead bearing flue dust.
With tar pitch	Oker Zinc Oxide Plant.	For crushed zinc bearing slags.

In addition to a number of the patents mentioned above.

For Iron and other Metal Swarf.

Gradual compression up to a high end-pressure.	D.R.P.	158,472	Rónay	As above under I. 3.
	D.R.P.	175,657	Weiss	As above under I. 2.
	,,	178,303	,, ...	Moistening with lime-water.

B. DESCRIPTION OF THE METHODS.

In the following pages the majority of the methods given in the above table will be dealt with in order, briefly, or completely, according to the requirements set down on p. 14. Examples of practical application and working results of their suitability will be given when it appears to be desirable.

The mechanical arrangements used in the operation of the more important processes are dealt with in the later sections.

I. Briquetting without Special Binding Materials.

If the ores are rich in iron, *i.e.* they contain in addition to the usual iron-bearing materials (iron oxide, black oxide of iron, hydrated oxide of iron and iron carbonate) only little gangue, this process is recommended by its simplicity. If, however, the ores are poor in iron, the gangue (especially clay), which is present in large quantities, acts partially or completely as a binding material, and there are therefore a number of possible intermediate processes between briquetting with and without special binding materials.

1. MIXING WITH WATER.

(*a*) Simple Hand-moulding.

Clayey ores are stirred with water to a thick paste, kneaded and moulded like loam bricks by the simple process of hand-moulding. In this way, for example, the Cornelia mine prepared its ores for the Cornelia smelting works in the middle of the nineteenth century, and even at the present time burnt pyrites are treated in a similar manner at Langloan, in Scotland. In the first case, the brick-making depends upon the presence of an iron-bearing clay, whereas in the case of the burnt pyrites or purple ore from the copper lixiviation plant the sodium sulphate left in the residue acts as bond.

In both cases, however, usable bricks are only obtained when all the water is expelled from the blocks by calcination. If this is effected in the blast furnace, the briquettes again fall to a powder.

(1) Compression with Moderate Pressure.

Mansfeld Mining Co.'s Method.

(For crude and calcined copper schist fines.)

An explanation is given on p. 6 as to what is meant by these ores. The fines freed from bitumen by heap-burning and raked out from the schisty shale are sieved and mixed up with water and the fine burnt schist residues from the sieving plant. They are then pressed into blocks by an ordinary brick press under no special pressure and embedded in the burning heaps. The lime and clay contents of the fine shale form the binding material.

The pressure amounts to 15 kw. at a maximum, and the presses are manufactured by the company's engineering shops at Sangerhutte, near Hettstedt. Output: an average of 1000 blocks per 9-hour shift.

Boys of from fourteen to seventeen years of age are engaged in working the presses. They are distributed as follows.

	2	for mixing the fines and carrying the mixture.
	1	for shovelling.
	1	for removing the pressed blocks.
	2	for carrying the blocks to the calcination heaps.
Total	6	

For each 100 pressed blocks, 8 kgs., about 32 pfennige are paid in wages.

2. COMPRESSION WITH MEDIUM OR HIGH PRESSURES.

Kertsch Iron Works Method.

(For argillaceous bean ores.[1])

At the Kertsch Iron Works in South Russia the local powdery, clayey, oolitic brown-iron ores (bean ores), containing 42 per cent. iron, are first sieved. The fine material passing through the 20 mm. mesh of the shaking sieve contains 17 to 18 per cent. water, and is dried at 500° to 600° C. in a Gröndal shaft furnace heated by means of coke-oven gas. It is then pressed to cylindrical briquettes (10 mm. diameter and 10 cm. high) in a Couffinhal stamp press under a pressure up to 100 atmospheres.

The output of the briquetting plant amounts to about 12,000 tons of briquettes per month. Costs amount to 1·50 marks per ton, exclusive of ...idation.

[1] Zeidler, *Stahl und Eisen*, 1905, p. 321 *et seq.*; and O. Simmersbach, *Z. Berg- ... Rundschau*, 1906, No. 14, p. 181.

As in the previous case, the clay contained in the ore obviously forms the binding material.

Other Methods.

If there is not sufficient clay or other binding material present in the ores, the preparation of good strong briquettes without the employment of additions, merely by the use of very high pressure, presents special difficulties, since care must be taken that the particles compressed together are not separated again by the expansion taking place when the briquette is heated in the blast furnace.

It has been shown in the patents dealt with under II. that various methods of overcoming this have been attempted, first and foremost in the direction of strengthening the external portions of the briquette. This is effected by setting up superficial oxidation, by heating in an atmosphere of carbon dioxide or smoke gas to produce a strong crust; by stamping a layer of special binding material, or casting molten iron round the briquette. But even if it be possible to prepare briquettes of great strength in any of these ways and to introduce them into the blast furnace without much breakage, it is still very doubtful if the briquettes would be sufficiently resistant to the action of the gases. In addition, consideration must be given to the increase in the costs of briquetting, which would certainly be too high in the last process.

The method of L Weiss (D.R P. 175,657) consists—in its application to certain ores, metal swarf, and salts—of a preliminary moistening of the briquetting material with dilute magnesium and calcium sulphate solutions. This treatment enables strong briquettes to be prepared by subsequent compression under a very high pressure. Such a slight quantity of salt solution can hardly act as a binding material, but should rather be described as a stimulating agent, since its addition is of considerable import, and the real success of the briquetting is not to be ascribed entirely to the bond contained in the ore or to the high end-pressure. The application of the process to metal scrap is described below.

According to the patent specification, the solution can be obtained very cheaply from the slimy residues of soda-water manufacture. During the decomposition of dolomite with sulphuric acid it is well known that a slimy residue is left, consisting of undissolved magnesium and calcium sulphates and a saturated aqueous solution of these salts. The aqueous solution is separated from the insoluble constituents by centrifugalising.

Three Methods by Dr W. Schumacher

(For flue dust, 1908.)

These depend upon the discovery that flue dust itself, as a result of its special composition contains greater or lesser quantities of hydraulic cement-like binding materials although in considerably different proportions from such hydraulic materials as Portland cement. When the dust is collected as it falls, and is simply moistened with water and compressed, it presents only a scarcely perceptible tendency to bind, and only then when treated in the fresh condition. Special means are required to effectively develop the power of binding.

A.—An addition of $\frac{1}{2}$ to 2 per cent. of a stimulating (catalytic) salt solution, such as for example magnesium chloride, iron sulphate, etc., has the effect of causing the blocks to bind together as soon as they leave the press. Almost immediately an increase in temperature of the briquettes takes place, the hardening process is complete in a few hours, when the briquettes can be removed direct from the press to the ore waggons and tipped into the ore bins.

Magnesium chloride can be obtained cheaply as a bye-product in the manufacture of potassium chloride.

B. The briquettes prepared from flue dust without any addition of catalytically acting salts, are treated with superheated steam in a hardening kettle for some hours. By this means quite a good bond is effected with many kinds of flue dust. The strength of these briquettes can be still further increased by the addition of small quantities—$\frac{1}{2}$ per cent.—of the above-mentioned salts before the compression process.

C.—The binding power of almost all varieties of flue dust can be increased in a satisfactory manner by lightly grinding the flue dust. This process only gives rise to very slightly increased costs (about 20 pfennige per ton) on account of the dry and finely granular condition of the powder.

Catalytic materials can be added to this ground dust, which is then pressed into briquettes and dried in the air. By using the steam-hardening process the addition of this material can be omitted in all cases.

Flue dust, particularly when it is ground, has in most cases so great a binding power, that it can be used with advantage as a binding material for other ores. Generally speaking, ore and flue dust can be mixed in equal quantities, but if the dust has specially strong

binding powers, the mixture may consist of 25 per cent. dust and 75 per cent ore.

Application of Method A.—The first plant using this method came into operation in May 1908 at the Haspe Iron and Steel Works. It was followed in 1909 by a provisional plant at the Dortmund Union, and a complete briquette factory at the Eisenhutten-Aktien verein Dudelingen (Lorraine).

At Haspe, the whole daily accumulation of 140 to 180 tons flue dust is briquetted, with an addition of 1 per cent. magnesium chloride and 5 per cent. plaster of Paris[1] The addition of plaster of Paris chiefly serves the purpose of increasing the pressing properties of the dust obtained, but can be omitted if a portion of the dust is ground according to the method given above. In 10 hours each of two presses yields 10,300 to 10,400 briquettes of 5·5 kgs. weight, equal to a daily (20 hours) total of 220 tons, since one of the presses is idle at night. After 24 hours' storage the stones are sufficiently hard, although the maximum hardness is not reached until after 48 hours.

At the Dortmund Union and at Dudelingen the dust is briquetted with 1 per cent magnesium chloride only Compression takes place in a large revolving table press of the latest type by Bruck, Kretschel & Co (with pneumatic counter pressure).

The briquettes produced by this method have an average strength of 150 kgs, satisfy all the demands of the smelting process, and influence the working of the furnace to advantage.

According to figures given by the constructors, the costs of briquetting per ton are as follows :—

Mixing, conveying, and briquetting . .	0·80 to 0·90 M.
Sinking fund, interest, and depreciation (maximum) .	0·30 ,,
Possible grinding of the flue dust . . .	0·20 ,,
Alternative addition of magnesium chloride . .	0·60 ,,
Possible steam hardening of briquettes . . .	0·20 ,,
Consequently the total costs amount to . .	1·50 to 1·80 ,,

3. GRADUAL COMPRESSION UP TO VERY HIGH END-PRESSURES.

A. Rónay's Method.

(D.R.P. 158,472 and subsidiary patents. Numerous foreign patents.)

Rónay's method, owned by the "Allgemeinen Brikettierungs-gesellschaft" (Berlin W. 64, Unter den Linden 8), is intended for appli-

[1] As a matter of fact, the Haspe method should be more correctly assigned to the processes working with a special binding material. See, however, the further information.

cation to ores, metallurgical products, and the swarf from iron, steel, and other metals. It is characterised by the fact that no binding material is employed, the dry or slightly moistened material is briquetted simply by subjection to very high pressures of 800, 1000, and even 2000 atmospheres

The whole pressure is not exerted suddenly, but is increased gradually or step by step, with the object of completely driving the air out of the material Only in the last stages of the process is the pressure permitted to rise to that height at which the material becomes plastic and binds together When necessary, the briquettes are subjected to the action of gases containing carbonic acid

Compression to the commencement of sintering is not aimed at, nor does it take place, but, with the very high final pressure and the resulting heating up of the briquettes, along with the physical changes chemical changes may be brought into play which probably contribute towards the bonding of the briquettes.

It has already been pointed out in the first volume of this book (Appendix, p 641) that the method, when somewhat modified, is suitable for the briquetting of fuels, salts, chemical products, and food stuffs. On these points further information is given below.

The Ronay method depends upon the following observations and considerations

The pressure of 300 to 700 atmospheres, usually applied for the production of ore briquettes without binding material, is not sufficient to convert into strong, resistant pressed blocks many of the fine ores, flue dusts, etc, which are only slightly or non plastic According to the results of numerous experiments, a minimum pressure of 800 atmospheres, and, in some cases, upwards of 2000 atmospheres, according to the nature of the material, is required for this purpose. In addition, this extremely high pressure must be applied in a special way

If a high pressure is suddenly applied to air dried or slightly moistened flue dust from all or two sides the mass becomes very plastic under a certain pressure and encloses the contained air, which is hindered from escaping, in the form of blow holes. When such a pressed block is introduced into the blast furnace the enclosed air is expanded at the high temperature prevailing, and this, in combination with the evolution of the moisture content, causes the briquette to be burst open. This emphasises the necessity of a compression which forces the air out of the mass—best effected by a step-by-step compression—and at the same time removes most of the water content, whether it has been added before the compression, is simply the natural hygroscopic moisture, or the water of crystallisation of the briquetting material. This requirement is provided for in the Rónay method in the manner described above

Presses.—In order to carry out the process in a practical manner it was necessary to design a suitable press. This was effected by the inventor. In its latest design the hydraulic press of the Rónay system completely fulfils all the various requirements. Its design is the property of the Allgemeinen Brikettierungsgesellschaft, Berlin. It is described and illustrated among the various briquette presses in Section V. Photographic reproductions of briquettes made by this press from various materials are given in fig. 3 (4-12), p. 21. They possess high or ample strength, with great density and porosity. The water content squeezed to the surface of the briquettes evaporates very rapidly under the influence of the heat of the press.

Possible Subsequent Treatment of the Briquettes.—Most of the briquettes prepared by the Rónay press can be charged directly into the blast furnace if they are to be smelted at the place of production. For transport to remote places, however, an after-treatment with products of combustion containing carbon dioxide is recommended. An action of 3 to 6 hours' duration is quite long enough to strengthen the briquettes sufficiently. Briquettes of fine ores of a crystalline nature (magnetic iron ore, red hematite, spathic iron ore), unless they are prepared by mixing with a plastic ore, such as clayey brown-iron ore, require heating even for smelting on the spot. In this case, however, the roasting need not be very thorough, and in fact only need lead to the production of a roasted crust at a red heat to prevent breakage of the briquettes on falling into the blast furnace. The roasting of the kernel can take place in the furnace itself.

Practical Application of the Method.—After the Rónay method had first been tried in a plant in the U.S.A. for the briquetting of magnetic fine ores, which are specially difficult to bind, it was further developed by the inventor in the experimental station of the Fritz Muller Engineering Works at Esslingen, where the Rónay hydraulic presses were built. Here the method was improved and tested in its application to various materials.

Since 1908 a briquetting plant with a single press installed close to the blast-furnace plant has been working at the Friedenshütte, Morgenroth O.S., taken over in 1909 by the Oberschlesische Eisenbahnbedarfs-Aktiengesellschaft, but is at present only in the experimental stage.

According to information supplied by the works management, from October 1909 the press delivered (under a final pressure of 960 atmospheres, calculated on the press material) quite strong and weather-resisting briquettes from various

materials.* At the present time the hourly output is about 300 blocks, each weighing from 7 to 9 kgs., equal to a total of 2·1 to 2·7 tons. The principal materials dealt with are burnt pyrites mixed with flue dust, converter dust, or 3 per cent. dry slaked lime. Since the tests are not yet complete, no results can be given as to the behaviour of the briquettes in the blast furnace and the economical advantages obtained.

According to two cost sheets communicated by the Allgemeinen Brikettierungsgesellschaft, Berlin, and dealt with in the section on complete briquetting plants, the costs of briquetting in a single press plant for a yearly output of 30,000 to 50,000 tons, inclusive of interest and depreciation, only amount to 1·80 M. to 1·25 M. per ton for the usual method of working without any subsequent treatment of the briquettes. This is very probably true, since the method offers as advantages great simplicity, low installation costs, low expenditure in wages, moderate power requirements (40 to 50 H.P. per press), and the absence of costs of binding materials.

With regard to the successful application of the Rónay method to the briquetting of iron and other metal waste consult the details given on p. 82 *et seq.*

The following information supplementing that given in the Appendix to Vol. I. indicates the form in which the Rónay method is adapted to the briquetting of coals, brown coals, and other fuels.

A special patent, D.R.P. 187,833, "Method for the Production of Briquettes from fuels or mixtures of fuels which cannot be briquetted alone. With special reference to non-bituminous coal and brown coals," has been taken out for the briquetting of fuels.

In this method the dry material is subjected to a very high but gradually increasing pressure in order to attain as complete as possible a removal of the air, and to cause a subsequent binding by means of the bitumen pressed out.

An addition to the foregoing patent protects a method of carrying out the foregoing, and has for its object a more complete removal of the air and better bonding, in order to obtain stronger briquettes. It consists in subjecting the block obtained by the method of patent 187,833 to the action of a suddenly applied, very high pressure.

A second mode of application is intended for fuels containing practically no bitumen or similar material becoming plastic under high pressure and then exerting a binding action. In such cases, small quantities of binding material are added to the press material. Bituminous materials, such as bituminous shale, hard pitch, clayey

materials, lime, cement, etc., whose binding properties only come into action under the suddenly applied end-pressure, are eminently adapted for this purpose

According to the results of numerous experiments, the Rónay process is able to produce, by the aid of either the first or second method of working, good strong briquettes from caking coals to the non-bituminous coals of the Ruhr and Saar districts, while an addition of 5 to 8 per cent of costly pitch must be added to these coals before they can be briquetted by the ordinary methods (see p 50 *et seq*, Vol. I.).

For very hard coals, such as anthracite and the hard coals of Upper Silesia, etc., an addition of 1 to 2 per cent. pitch or the corresponding amount of fat coal is sufficient for briquetting by the No. 2 Rónay process.

Tests carried out at an official testing station in the German Empire show that Rónay briquettes made from Westphalian fine coals have the very high degree of cohesion of 74, as against 54 for the Westphalian ship coal (see pp. 22 23, Vol. I).

The omission of the bond provides, in addition to a considerable economy, the further advantage that no premature disintegration of the briquettes and no development of smoke (owing to fusion and combustion of the binding material with a smoky flame) can possibly take place.

The resistance to weathering and capacity for storing Rónay coal briquettes cannot be less than that of good blocks of coal.

The ability of the Rónay process to make good briquettes of hard brown coals (which can only be treated with difficulty by other methods), of saw-dust and other wood waste, has been proved by experiment.

Up to the present, the process (so far as is known) has not been applied to coals, brown coals, and other fuels, but the construction of similar plants at a number of works has already been planned or is in actual operation. If it is successful on the large scale, and fulfils all the requirements with regard to quality of briquettes, a great future is before it, and the production of briquettes for firing will be considerably advanced.

4. SINTERING METHODS.

General

The various sintering methods dealt with on pp. 29, 30 have for their object the combination of the particles of fine ore by sintering or

fritting together at high temperatures. The operation may take place after the production of pressed blocks which still require strengthening, or without moulding under pressure. In the latter case, the particles of fine ore are balled up into lumps and sintered, this constituting the process of agglomeration.

In all sintering operations the sintering temperature must be distinguished from the fusion temperature, and experiments must always be made to determine the relation between the sintering temperature and the melting point of the ore to be worked up. There must be ample play between these two temperatures.

The difference between the sintering and fusion temperature is 200° C. to 250° C. in the case of magnetic iron ores, and falls to 150° C. in the case of purple ore, to 100° C. in flue dust, and in many other ores to between 30 and 40° C.

In general the suitability of the ore increases with this temperature difference, but, in addition, the degree of oxidation of the crude ore and its physical nature are of considerable importance.

Magnetic iron ore is most suitable, on account of the considerable interval between the temperatures in question, and also on account of its being composed of the easily fusible black oxide of iron (Fe_3O_4) and because of its coarsely crystalline structure. The bean ores of Salzgitter are, however, very unsuitable for sintering, because they consist of brown iron ore. This gives rise to the almost infusible oxide (Fe_2O_3), which is difficult to deal with because of its smooth, hard surface. The large-scale sintering experiments carried out on Salzgitter ores by the Gröndal process have also been unsuccessful.

The main grounds for the necessity of an ample interval between sintering and fusion temperature are the difficulty of maintaining the fire gases at a constant temperature, and the danger that on overstepping this temperature the material fuses. In the latter case, there is obtained a slag which is quite unsuitable for smelting. But even a partial melting of the particles of ore, or the formation of a fused crust on the briquettes subjected to the process, is fatal. Primarily, the success of a process of sintering depends upon this danger being safely guarded against.

From the point of view of economy, the high fuel or energy consumption is disadvantageous, since the various sintering processes require the production of very high temperatures (1200 to 1400° C.). Normally the coal consumption is 4 to 6 per cent. of the weight of the briquette, and about 7·5 per cent. when it is desired to effect desulphurisation. Low fuel costs are, therefore, of great importance. The con-

ditions are most favourable at a coal pit or a coking plant, where there is an ample supply of fine coal or waste coke otherwise difficult to dispose of, or again, where there is waste gas, or, in the case of electro-thermal sintering, where there is very cheap electrical energy.

(a) Sintering after Complete Pressing.

The Grondal method of sintering pressed blocks in a channel furnace has, up to the present, proved itself the best, and found widest application of all the various processes.

The method of Gustav Grondal of Stockholm is admirably suitable for fine magnetic iron ores (crude ores or slimes from the wet and magnetic preparation of finely crushed poor ores), and also for magnetic ores.

The fine ores or slimes are slightly moistened if dry, and dehydrated to a large extent if wet, and then pressed to bricks by means of a stamp press These briquettes are then carefully removed by hand to special briquette waggons The waggons are then drawn by means of a Gall chain into a brick channel furnace about 56 metres long, are slowly pushed forward continually, and subjected to the heat of gases (producer or flue gases or a mixture), which are burned with pre-heated air in the channel oven and caused to impinge on the waggons. Beyond the zone of combustion the waggons and their contents of briquettes cool down, and finally leave the other end of the oven, in which they have remained about nineteen hours. The briquettes can be used immediately, and after further cooling in the open air they can be sent for transport. The weekly output of a channel oven amounts to about 200 to 350 tons of briquettes.

Quite superior briquettes of great strength, hardness, and porosity (see fig. 4 (1 and 2)) can be prepared in this manner from magnetic iron ores and purple ores by fritting at 1300 to 1400° C. Burning in a channel oven also has the effect of reducing the sulphur content of the ore to very minute quantities.

Practical Application of the Method.—The first Grondal channel furnace was put into operation in 1902 at Bredsjo, in Sweden, and was heated by flue gas. Since then the Grondal patent, owned by the "Metallurgiska Aktiebolaget" of Sweden, has up to 1908 been responsible for the erection of thirty similar furnaces, whose yearly output is about 400,000 tons of briquettes. In addition, plants have been built at other smelting works in Sweden: a number have also been built in Finland, Norway, Spain, Germany, and other countries.

According to a communication by C. Akermann, the following plants were working the Grondal method towards the latter part of 1907:—

SWEDISH BRIQUETTING PLANTS ON THE GRONDAL SYSTEM.[1]

Works	Proprietors	Yearly Output
		tons
Carlsvik	Luleå Jernverks Aktiebolag	60,000
Herräng	Herräng Grufaktiebolag	40,000
Guldsmedshyttan	Guldsmedshytte Aktiebolag	30,000
Strassa	Strassa Grufbolag	100,000
Bredsjö	Aktiebolaget Bredsjö Bruk	30,000
Hjulsjö	Aktiebolag ,, ,,	10,000
Oestanfors	Uttersbergs Bruks Aktiebolag	10,000
Helsingborg	Helsingborgs Kopparverk Aktiebolag	80,000
Riddarhyttan	Riddarhytte Aktiebolag	30,000

In Germany attempts were made to apply the method to the briquetting of the Salzgitter bean ores, but the experiments failed on the grounds mentioned above. The method was also a failure at Witkowitz (Austria). Recently, however, it has been applied with success to magnetic iron ores at the Christoph mine at Schwarzenberg, Saxony, and to roasted spathic ore at Kreuzthal, near Musen (Siegerland).

In the section on complete briquetting plants, a detailed description is given of the magnetic iron ore and briquette works at Flogberg, Sweden, working under the Grondal patents. Diagrams, flow diagrams, installation, and working costs are also given. In addition, several other Grondal installations are dealt with.

In Sweden the costs of briquetting by the Grondal method amount to about 4 M. per ton (inclusive of sinking fund and interest), and are therefore to be considered as high.

Application of the Grondal Briquettes in the Blast Furnace.—According to Johansson,[3] more briquettes can be charged into a furnace producing Bessemer pig than into one producing open-hearth pig. They are specially suitable for the production of the low-phosphorus Swedish irons, for which purpose the low-valued black ore requiring the use of a very high proportion of charcoal had formerly to be applied.

Further, by increasing the proportion of briquettes the total ore charged

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[1] Z. *Revista minera*, 1907, Nov. 24, p. 552; *Stahl und Eisen*, 1908, No. 9, p. 311.

[2] This figure is too high; 25,000 tons is the correct yearly output. *Cf.* J. Hyberg, *Kalender för Sveriges Bergshandtering*, 1908, p. 112.

[3] Z. *Jernkontorets Annaler*, Stockholm, 1908, Nos. 4 and 5, pp. 400 *et seq.* and 434 *et seq.*

can be increased, while the coal consumption is decreased. Since, however, the briquettes are more expensive than lump ores, the economical results obtained do not appear in so favourable a light. This will be evident from the following table

COMPARISON OF THE WORKING OF A SWEDISH BLAST FURNACE BEFORE AND AFTER THE ADDITION OF GRONDAL ORE BRIQUETTES (A. JOHANSSON)

Year	Brand of Pig Iron	Briquettes in per cent of Charge	Percentage Iron Content of Briquettes	Per cent Iron in Charge		Coal Consumption in hl. per ton when using Briquettes	Ratio of Coal used.		Average Weekly Output in tons when using Briquettes	Ratio of Weekly Output		Ratio of Price per ton of Charge		Ratio of Costs of Production per ton of Pig Iron	
				Before addition	After addition		Before addition	After addition		Before addition	After addition	Lump Ores	Briquettes	Before addition	After addition
1908	Bessemer	34 7	65	57 4	61 2	61 3	1	0 92	152 6	1	1 [illegible]	1	1 [illegible]	1	0 950
1908	,,	21 3	6[illegible]	6[illegible] 5	62 5	68 8	1	0 81	123 2	1	1 [illegible]	1	1 [illegible]	1	0 913
1907	Martin	[illegible]8 7	65	65 0	58 8	60 7	1	0 92	151 4	1	0 99	1	1 44	1	0 940
1908	,,	50 0	62	62 5	62 3	59 1	1	0 82	151 6	1	1 21	1	1 53	1	0 952
1906	,,	16 0	65		.	49 0	1	0 74	117 6	1	1 26	1	1 50		

Coltness Method[1]

The method of briquetting carried out on fine brown iron ores from Almeria (Spain) by the Coltness Iron Co. Ltd., Scotland, differs from the Grondal process mainly in that the pressed blocks are first dried and then calcined in a Hoffmann's ring furnace.

At the Coltness works the fine ores passing through a ¼ inch sieve (one third of the total quantity of ore) are finely ground, mixed with water, and pressed into bricks 10″ × 8″ × 6″. These are, however, very weak, and are therefore carefully loaded into cars and charged by hand into one of three neighbouring drying-rooms. They remain here overnight, are subjected to the action of waste gases entering at a temperature of 150° C. from the roasting furnaces, and acquire sufficient strength to be stacked in the ovens.

The calcining ovens are of the Hoffmann type, arranged in three blocks, each of 12 ovens in two series placed back to back, with a heating channel down the centre. Each block can accommodate about 6500 briquettes. The furnaces are heated by means of blast-furnace gas, introduced gradually during the first 12 hours in order to drive out all the moisture slowly. During the next 12 hours the gas supply is increased until, after 48 hours, the maximum temperature is attained. The furnace is then allowed to cool

[1] O. Simmersbach, *Z. Berg- und Hüttenmann Rundschau*, Kattowitz, 1906, No. 14, pp 181 182, where the briquetting plant of the Coltness Iron Co. is illustrated in plan.

down, and after a sojourn of 14–15 days the briquettes are removed by hand. They weigh 29 to 30 lbs., and are all smelted in blast furnaces.

Disadvantages of this method are (1) difficulty in regulating the temperature, resulting in overheating of the bricks in the lower part of the furnace, while those in the upper portion are not calcined sufficiently; and (2) the large amount of hand work, which largely increases the costs of briquetting. No numerical data are to hand with regard to the process.

Of the remaining sintering methods for briquettes, none have met with any noteworthy success up to the present.

(b) Sintering without Compression (Partial Agglomeration).

Method used in Raduschewitz, Olonetz.[1]

This method which has been applied with success at Raduschewitz, Olonetz, N. Russia, consists in calcining finely divided iron ores moistened with cheap combustible materials like wood tar, naphtha residues, etc., without previous recourse to briquetting. Roasting is carried on until the ore sinters to a porous mass. Details, with regard to the mode of operation, costs, and results of the process, are not available.

Agglomeration in Petersson's Calcination Furnace.[2]

This method utilises the roasting furnace (D.R.P. 159 485) invented by G. O. Petersson of Dalsbruk, Finland for finely divided ores, dolomite, etc. In this furnace, which is provided with alternating chambers arranged stepwise one above the other and connected together, the fine ore charged in at the top gradually rolls automatically from step to step, and is, at the same time, subjected to the action of hot gases introduced below. On the bottom step, where the ore is subject to the greatest heat, it sinters to lumps of irregular size and shape (see fig. 6 (6)), and is ultimately discharged from the furnace when it is ready for smelting.

The process (using blast furnace gas) has been applied on a working scale since 1908 for the electro-magnetically concentrated magnetic iron ore fines at the Langsbanshyttan blast furnaces in Central Sweden. The plant is described in the section on "Complete Agglomeration Plants," with illustrations of the furnace. Under the local conditions the process is described as working quite favourably, the working costs amounting only to about 1·40 M. per ton.

[1] Z. *Stahl und Eisen*, No. 10, p. 325.

[2] G. Franke in Z. *Glückauf*, Essen, 1908, No. 41, p. 1458; and G. Ekman in Z. *Blad for Bergshandteringens Vanner inom Orebro Lan*, 1909, No. 9, p. 340 *et seq.*

Scott's Shaft Furnace Agglomeration.[1]

According to the process patented in America by James Scott, fine ore and flue dust are shaken into a shaft furnace through a sieve. The materials are sintered together and fall into tooth rolls at the bottom of the furnace, where they are kneaded together and simultaneously discharged. Apart from the toothed rolls, the process is very similar to the one previously described.

Agglomeration in Revolving Tube Furnaces.

The long-inclined tube furnaces slowly revolving on rollers, which are so frequently employed in the cement industry, are employed in this process. The furnaces are lined with blocks of refractory material the fine ore is charged at the upper end, whence it rolls and slides to the lower end, and at the same time is subject to the action of a counter-stream of gases These gases (flue gases, producer gases, or a mixture of fine coal or coke powder and air) are blown into the lower end of the furnace through an inclined nozzle, and at the point where the jet of flame strikes the pre-heated fine ores the particles are converted into a sintered plastic mass. This becomes balled up into spherical—egg—or irregular shaped lumps of various sizes by the continued rotation of the furnace (see fig. 6 (2-5)). These lumps roll out of the furnace, and before smelting or transport can be cooled to any required degree by passing through a similar tube drum situated at a lower level, and through which cold air is passing.

A plant of this description, with two tube furnaces and two cooling tubes (constructed by Fellner & Ziegler of Frankfurt a M., Bockenheim) is described and illustrated in the section on "Complete Agglomeration Plants." Examples of the application of the method on a working scale at Trzynietz, near Teschen (for burnt pyrites, fine spar, and flue dust), and at Giessen (for manganese ore and Siegerland fine spar) are also described in detail. The costs of production amount to about 3 M. per ton.

In North America, sintering and agglomeration has been carried out in a revolving tube furnace since 1905, in accordance with a patent acquired by the National Metallurgical Co. In order to facilitate the balling up of the grains and the reduction in the sulphur content (and other detrimental impurities), the fine ore is first mixed with a material acting as binder. This material exerts a reducing action,

[1] Flaccus, *Stahl und Eisen*, 1908, pp. 993-994.

becomes tacky at a low temperature, volatilises at a somewhat higher temperature (about 600° C.) when it has a chemical affinity for and combines with such materials as sulphur giving volatile compounds.[1] In actual practice, such hydrocarbons and carbohydrates as tar, pitch, petroleum residues, dextrin, and molasses are admirably suitable provided they can be obtained at a sufficiently low price. An addition of 1 per cent. is ample (see Raduschewitz Sintering Method, p. 45.)

The tar, etc., is dropped or sprayed steadily on to the stream of fine ore automatically charged into the upper end of the revolving furnace, and causes the mixture to become tacky, resulting in the formation of granules or small lumps on further rotation of the furnace. When this material comes into the heated zone of the furnace chemical combination takes place between the sulphur and tar resulting in the formation of a volatile compound. In the lowest and hottest zone (at about 1100° C.) sintering and agglomeration to strong coarse lumps takes place. Ores whose melting points are situated at widely varying temperatures, such as burnt pyrites, magnetic iron ores, Mesabi ores, flue dust, Franklinite, etc., are agglomerated in this way in America.

Since 1905 the National Metallurgical Co. have operated by this method agglomeration plants in Newark (with a Henderson copper lixiviation plant in which special revolving furnaces are used for roasting the mixture of burnt pyrites and salt) and Aspinwall, Pittsburg, Pa. (for burnt pyrites and flue dust from the neighbouring sulphuric acid plants and blast furnaces, which latter produce large quantities of dust on account of the great amount of fines in the ores from the Mesabi and Lake Superior districts).

The Pennsylvania Steel Co., under license from the National Metallurgical Co., have, since 1905, agglomerated magnetic concentrates and fine ores from the above districts in admixture with flue dust from their own blast furnaces at Steelton, Pa. Four tube furnaces deliver about 150 tons of agglomerates per hour.

The analyses of the fine magnetic iron ore at Steelton before and after agglomeration are approximately as follows:—

	Before Agglomeration per cent.	After Agglomeration per cent.
Iron	59·64	61·24
Sulphur	1·15	0·13
Phosphorus	0·01	0·01
Silica	8·50	8·61

[1] A. L. Colby, *Jour. Iron and Steel Inst.*, London, 1906, pp. 351-376 (Plates xxxi.-xxxix.); further references are given in "Progress in Agglomeration and Desulphurisation of Fine Ores in America," *Z. Berg- und Huttenmann. Rundschau*, 1906, No. 4, pp. 47-49.

The New Jersey Zinc Co. successfully agglomerates at Hazard, Pa., the fine ore obtained by roasting ground Franklinite on open grates. Only a very slight loss of zinc is experienced in this way, e.g. the zinc content of the fine ores before roasting was 17.4 per cent., while that of the agglomerate was 20.1 per cent.

The Empire Steel and Iron Co. of Catasangua, Pa., owning one of the largest magnetic iron ore mines at Oxford, New Jersey, intends, after sinking a second shaft, and increasing the output to about 16,000 tons per month, to concentrate the whole of the ores, and to agglomerate the fine ores containing about 55 per cent. iron, and which are apparently rich in sulphur.

According to Colby,[1] the smelting of agglomerates of burnt pyrites, magnetic iron ores, and flue dust was carried on at six different American blast furnace plants in 1906. Several were charging over 50 per cent., with such satisfactory results in every case that the demand exceeded the supply.

5. FUSION (PARTIAL AGGLOMERATION)

The older processes dealt with in the table on pp. 29, 30, which endeavoured to convert fine ores into the lump form by fusion in a reverberatory furnace, whether by the aid of fluxes or reducing agents, gave rise to unsuitable slags. In addition they were too costly to be widely used. Further, the later experiments on the fusion of flue dust in the Martin furnace,[2] by means of flue gases passed through regenerators, did not lead to very satisfactory results, since the product resembled puddler's cinder, and the refractory material of the furnace did not stand up to its work.

The various new American processes of Ruthenburg and others are of interest, though not of practical importance. Attempts are made to agglomerate, or to convert directly into iron or steel, fine ores by fusion in electric furnaces.

Ruthenberg's Electric Roll Oven Process[3] (D.R.P. 156,152)

was the first attempt to work up the fine American magnetic iron ore concentrates electrically.

The concentrate, mixed with a suitable fuel, is allowed to fall from a hopper whose lower portion is wound with wire, between two bronze rollers covered with gas carbon revolving in opposite directions, somewhat similar to a roll crusher. The core of the rolls

[1] See footnote on previous page.

[2] *Stahl und Eisen*, 1908, No. 3, p. 98.

[3] *Eisenzeitung*, 1904, pp. 469–471; *Z. Gluckauf*, Essen, 1905, No. 4, p. 111; A. Neuburger, "Beitrage zur Elektrometallurgie des Eisens und Stahls," *Gluckauf*, 1906, No. 19, pp. 611–613.

consists of two powerful magnetic poles, round which a current of electricity passes during the operation. A water cooling arrangement is provided between the core and the bronze cylinder.

The fine particles of magnetic ore passing between the rolls become strongly heated by the current and are held fast by the magnets, so that they form a glowing hot bridge. As they are heated, however, they lose their magnetism, frit together, fuse and trickle down in the form of individual drops, which on solidifying assume a bean shaped appearance.

These agglomerates (beans) can either be smelted in the blast furnace or converted directly into metallic iron or steel.

With the latter object in view Ruthenberg allows the beans to fall into a brickwork shaft, up which reducing gases (blast furnace gas or producer gas from poor fuels) are passing, when reduction takes place to spongy iron.

According to a report of a Canadian Commission,[1] Ruthenberg mixes the magnetic iron ore concentrates with coke and saw dust in the ratio 80 : 20 : 5.

Taking into consideration these admixtures, the charge had the following composition:

SiO_2 .	0·93 per cent
Fe_3O_4	69·98 ,,
Fe (combined in other ways)	1·98 ,,
TiO_2	2·29 ,,
C	19·16 ,,

Analysis of the beans gave the following figures:

SiO_2 .	1·71 per cent	2·00 per cent
Fe_3O_4	77·13 ,,	90·95 ,,
Fe .	3·90 ,,	4·40 ,,
TiO_2	2·24 ,,	2·63 ,,
C .	14·72 ,,	

The first column of figures gives the composition of the agglomerate, while the second indicates the changes undergone by the iron ore, and therefore shows the composition of the beans when the carbon content is left out of consideration.

From these analyses, it follows that the reduction of the magnetic iron ore considered as such is very incomplete. The method is, however, of the highest value regarded as a method of agglomeration, although

[1] Eugene Haanel, "Report on Experiments made at Sault St Marie, Ontario, under Government auspices, in the smelting of Canadian iron ores by the Electro-thermic Process."

it is very costly. The narrow space between the magnetic poles is a great stumbling-block to the use on the large scale

Power Consumption.—According to the report of the Canadian Commission, the conversion of a ton of ore requires 0·054 H.P. Ruthenburg himself gives the pressure necessary for fritting as 100 volts, and that necessary for fusion 15 volts, the power consumed is 250 kw. hours per ton of ore, corresponding to an efficiency of 65·5 per cent.[1]

Galbraith and Stewart's Electric Resistance Furnace Method[2]
(B.P. 25,032, 1903)

is intended primarily for the magnetic iron sands of New Zealand, containing upwards of 70 per cent. Fe, 1 to 4 per cent. TiO_2, and only small traces of sulphur and phosphorus. According to Peters, the yields obtained during experiments in a resistance furnace were very small. It was placed beyond doubt, however, that such a furnace fused and reduced the fine ore to beans, which afterwards combined to irregular lumps in the uncooled collecting vessel.

The oxide of titanium, with the assistance of the ash of the coal dust added to the iron sand, should pass into the slag. A 100 kw. furnace should be able to work up 280 tons of ore per year, using 0·4 H.P. year per ton of iron.

The Electric Arc Furnace Method of E. Gates[3] (Am. P. 780,716)

endeavours to agglomerate by striking an arc between two inclined streams of the material. The arc passes between the two falling streams along the line of least resistance, and the rate of supplying the ore must be greater than is required to use up the whole of the energy of the current. The corn- to bean-sized lumps fall into a trough, where they cool down to a certain extent, and are enlarged by fused particles. While still hot, they are passed to a hopper and allowed to fall on to a revolving sieve. The fine material falling through is again passed through the plant.

Of the later electrical melting and reduction processes, the rotating electric contact furnace, combined with a revolving roasting and reduc-

[1] Peters, "Die Elektrometallurgie in 1905 und ersten Halbjahre 1906," *Gluckauf* 1906, No. 45, p. 1469.

[2] *Gluckauf*, 1906, No. 45, pp. 1469–70.

[3] Peters, "Die Elektrometallurgie im Jahre 1905 und ersten Halbjahre 1906," *Gluckauf*, 1906, No. 45, p. 1470.

tion furnace,[1] is of special interest. It is intended for working up fine **ores**: *e.g.* concentrates from iron sands, which are (in order) roasted, reduced, and fused to electric steel without being agglomerated.

The furnace plant consists of four inclined revolving tube furnaces arranged one above the other in zigzag fashion. While the upper two furnaces are used for roasting, the lower pair serve for the purposes of reduction. The fine ore trickles first from a charging hopper into the upper furnaces and thence into the lower furnaces. Between the second and third furnaces the reducing agent is supplied. At the same point an inclined blast pipe projects into the second furnace. The fourth oven communicates at its lower end with the chamber of an electrical contact oven, into which reducing gases, pre-heated to 800° to 1000° C., can be introduced through one or more blast pipes. In the contact oven the melting heat is attained by means of the electrical resistance of the material to be fused. Its lower part is provided with two channels into which the contact blocks dip from the outside of the oven. The channels are provided with tap holes, through which the melt flows steadily into a fore-hearth, from which it can be tapped off.

The revolving tube furnaces are provided internally with longitudinal projections, *e.g.* bricks set in the lining in order to effect movement of the material during rotation and to bring it into better contact with the gases. The roasting temperature is obtained by combustion of the gases from the reducing ovens along with the pre-heated air blown into the second furnace. The amount of air under pressure is so regulated that no fusion of the charge can possibly take place. During its passage into the third oven the roasted material is mixed with coal. No air is blown into the reducing chamber, in order to prevent the temperature rising too high. The reducing gases can be pre-heated electrically by passing them through tubes of refractory conducting material.

Some time will have to elapse before it is determined whether, and to what extent, this furnace plant is technically and economically successful, on the large scale, and whether it renders practicable the smelting of fine ores without previous resort to briquetting or agglomeration.

II. Briquetting with addition of Binding Material.

The inorganic and organic binding materials dealt with in the **table** on p. 29 *et seq.*—with the exception of iron ores, silicate of lime, **slags**, kieselguhr, and some salts—have all been applied to, or have

[1] Peters, "Neuerer über die elektrische Eisen und Stahlerzeugung, *Glückauf*, 1908, No. 39, p. 1390, with fig. 16.

been suggested for, the briquetting of coal and coke, and are therefore dealt with on p 38 *et seq.* and p 60 *et seq.* of Vol. I. of this Book. Generally speaking, these pages can be referred to in this connection, but further information with regard to the suitability and application of such materials to the briquetting of ores will be given in the following pages. Any inorganic binding material not described in Vol. I. will be dealt with fully in connection with the method using it

A. BRIQUETTING WITH INORGANIC BINDING MATERIALS.

1. Briquetting with Iron Ores.

The application of iron ores as binding materials at many works results from the existence of steady supplies of certain suitable ores, and also from the endeavour to diminish, as far as possible, the impoverishing of the charge by addition of other materials.

(*a*) **Briquetting with Argillaceous Ores**.—The clayey ores already spoken of on pp. 32, 33 are specially suitable. In each case it is necessary to add in the form of ore, sufficient clay to enable the briquettes to hold together at high temperatures, and to subsequently heat them sufficiently to expel the three molecules of water of hydration from the clay. Briquettes which are not so treated gradually fall to pieces on exposure to moist air

At the Concordiahutte, lump ores are mixed with ferruginous clays, which could be smelted alone if their physical properties permitted of it. The mixture is compressed to blocks, and consolidated by rapid heating like loam bricks.

In *Henzel's Method* a mixture of burnt pyrites and clayey ore has been successfully treated in a similar manner

The Ilseder Hutte method of briquetting, dealt with below, utilises clayey washery slimes or their own clayey crude ores for bonding limey washery sands, burnt pyrites, flue dust, and so on.

Methods used at the Ilseder Hutte.[1]

Although the production of Ilseder ore briquettes is mainly of local importance, the method possesses many points of interest. The Ilseder Hutte operates only on its own ores, with small additions of puddler's cinder. Most of the ores are obtained by blasting and quarrying the local deposits of limey brown-iron ore conglomerates while a smaller quantity is obtained from mines In this way the soft

[1] *Stahl und Eisen*, 1908, pp. 322 23.

ores, deficient in chalk and therefore richer in iron are separated into the powdery binding material containing lime and clay and into lumps and pieces of the real ore. The largest pieces are sent to the smelting plant as chalky ores, while the powdery material is subjected to a simple wet dressing during which the nodules of ore are separated.

This "washed ore," obtained in the size of beans is free from lime, and when dried at 100° C. contains about 50 per cent. Fe, 1 per cent. Mn, and 1·3 per cent. P. In addition, there is also obtained during the washing washery sand (a granular mixture of fine chalk and particles of ore) and washery slimes containing 60 per cent. moisture and the clayey binding material in a finely divided, slimy state. These materials were formerly regarded as waste products, and their disposal was a costly process. The assumption that a combination of these three products in the proportions in which they are obtained in the washing process should give rise to strong briquettes under suitable pressure was easily proved to be correct by experiment. Naturally, in place of the washed ore, which can be smelted directly, other iron bearing materials such as flue dust, purple ore, roll cinder, iron granules from basic slag, etc., must be added. A long series of experiments showed that perfectly strong briquettes could be prepared, not only in the manner indicated above but also by the application of clayey crude ores occurring in the local pits, along with fine iron bearing materials.

It was shown that the material to be worked up only gave a really strong briquette when the maximum moisture content was 5·6 per cent. On the large scale, therefore all wet additions were dried in a long rotating drum (by Petry & Hecking, Dortmund) heated with blast-furnace gas. Further, it was shown that the strength of the briquettes increased as the material was pressed at a higher temperature. On this account a quantity of about 5 tons of the material is always kept in a steam-heated mixing machine (by Bruck, Kretschel & Co. Osnabruck).

The hot, intimately mixed briquetting material passes directly from the mixing machine to the two powerfully built presses (by the above firm) and the briquettes are produced under a pressure of 300 kgs. per sq. cm.

Systematic experiments with gradually increasing pressures have shown that above a pressure of 300 kgs. the blocks are not further compressed to any considerable extent. This can easily be seen from the curve accompanying the description of the presses in Section V.

In order to hinder cooling of the briquette mass to as great an extent as possible, the front press stamp is kept hot by circulating steam through it. Each press produces on an average 18 blocks per minute; the briquettes at a temperature of 70° C. fall from the press on to a band conveyor leading to the transport waggons.

The output of the two presses amounts to 140 tons in 10 hours

Strength of the Briquettes.—Immediately after leaving the press the briquettes have a strength of 40 kgs., which is increased to 60 or 80 kgs. after a very short time, owing to the evaporation of hygroscopic moisture. When completely cold the strength is increased to 100–120 kgs. Experiments with heated briquettes have shown that the strength increases rapidly with the temperature. Briquettes at 600–800° C., and also after cooling, possess a compressive strength of 160–180 kgs. At 1000° C. the briquettes become reddish-brown, but still remain strong and maintain their shape; at 1400° C. they begin to sinter, become bluish and porous, but even in this condition maintain a compressive strength of 160 kgs.

It appears, therefore, to be of decided advantage to subject the briquettes, after coming from the press, to a heating process, in order to completely remove the water of hydration from the clayey binding materials and render the blocks more resistant. Existing conditions, however, do not permit of the installation of a roasting oven.

The pure costs of production of the briquettes amount to 80–90 pf. per ton, and are therefore low.

The influence of this lumpy pressed material, which maintains its size and shape at high temperatures, has proved to be very favourable on the running of the furnace, the coke consumption, and the formation of flue dust.

In consequence, briquetting at the Ilseder Hutte has fulfilled the twofold object of diminishing the costs of removal of the waste from the ore-washing plant, and has protected the furnace from the detrimental effects of such fine materials as iron ore, roll cinder, and basic slag waste.

(*b*) **Briquetting with Brown-Iron Ores.**—Quite analogous to clay with regard to physical properties is powdery brown-iron ore. It is, similar to clay in composition, contains three molecules of water of hydration, is plastic, and after powerful compression, followed by heating to drive off the water of hydration, can be made to yield strong bricks. Kleist's method is based on these facts, and will bind together Upper Silesian ores (finely granular brown-iron ores) with other ores,

such as magnetic iron ore and purple ore, in such a way that the bricks, after calcination at a high temperature, stand up very well in the blast furnace. According to an old process practised at the Georgs-Marienhutte, brown iron ores in the form of the liming waste from the purification of illuminating gas could be used but in view of the high sulphur content (the material being applied with advantage for the removal of this element in gas works) the material is unsuitable.

(c) **Briquetting with Spathic Iron, Clayband or Blackband Ores.**—Dr Schumacher's method for the utilisation of these materials is dealt with on p. 57, on account of the addition of milk of lime, which is necessary to the process.

(d) **Briquetting with Purple Ore.**—Purple ore has been used as bond in the briquetting of such fine ores as magnetic iron ore and flue dust, and in some cases with success. This however is to be ascribed to the special nature of the ores and flue dusts utilised.

(e) **Briquetting with Flue Dust.**—Experiments made on the use of flue dust as binding material for burnt pyrites, etc., have failed. According to Dr Schumacher however there are flue dusts possessing a certain degree of latent hydraulic properties which can be developed by the addition of small quantities of exciting (catalytic) agents, such as magnesium chloride, etc. On this notion depends the method, already dealt with on p. 35, for briquetting suitable flue dusts without the addition of a real binding material. In the same way, flue dust treated with magnesium chloride could be used advantageously in the briquetting of other iron ores.

In the following methods inorganic binding materials other than iron ores are dealt with exclusively. They all possess the unavoidable disadvantage that they lower the iron contents of the ores to be briquetted.

2. Briquetting with Clay.

It has already been repeatedly pointed out that clay is an excellent binding material. It must, however, be mixed with the ores in such quantities that after expulsion of the three molecules of water of hydration the material still holds together sufficiently. In this way the ore always becomes deficient in iron, so that the use of pure clay is impossible, and there only remains the use of argillaceous ores, which are only available in special cases.

3. Briquetting with Lime.

The table on p. 30 indicates the existence of a large number of processes depending upon the use of lime in one or other of its forms.

(*a*) **Briquetting with Calcium Carbonate** ($CaCO_3$) — Extensive researches were made a long time ago with this material, and have since been often repeated. In every case it has been proposed to powder and intimately mix the iron ores with the necessary limestone and fuel in the form of coke. These are the materials which interact in the blast furnace. This method, completed by suitable briquetting, could, however, never lead to favourable results in the furnace, firstly, on account of the unavoidable direct reduction by carbon which would accrue, and which is always regarded as disadvantageous, and also because the layers of coke, which should be distributed as evenly as possible, cannot be avoided.

The method of L. Weiss of Budapest (D.R.P. 183,108) operates quite differently. In this process the briquetting material is prepared with slaked lime ($Ca(OH)_2$), and during or after compression is treated under pressure with cold and then hot carbonic acid in order to convert the binding material rapidly and completely into calcium carbonate and bring about an immediate hardening of the briquettes.

If specially porous briquettes are required, the briquetting material is mixed with coke breeze, and the briquettes produced are subsequently roasted, when the coke burns and leaves fine channels in the briquettes.

The inventor of the process recommends that the process be combined with the operation of lime-burning, because all the bye-products can be utilised in carrying out the method. The carbonic acid can be exhausted through a compressor, and one portion collected in strong steel cylinders for the first stage of the operation, while the remainder is forced from the kiln direct to the moulds under a pressure of 18–25 atms., and at a temperature of 300–400° C. Dry slaked lime is mixed with wet material, and milk of lime is mixed with dry material. The whole of the lime content of the briquettes should be converted to calcium carbonate in 1–3 minutes.

These bricks maintain their strength in the blast furnace, if not to complete reduction, at least up to a temperature of 600° C., when the carbon dioxide is driven off from the calcium carbonate. The briquettes then fall to pieces. It is also of great disadvantage that the expulsion of the carbonic acid requires a certain amount of heat which might otherwise be utilised in the reduction.

If from this cause an increased amount of coke is required, the cost

can be saved by the economy effected in the diminution of the limestone added. So far as is known the process has not yet been used on the manufacturing scale.

Dr Schumacher's spathic iron-ore lime method depends partially on an artificial production of calcium carbonate.

The method of working is apparently the same as that of the quartz-meal lime method (p. 59). Crude spathic iron ore or other iron carbonate is finely ground and mixed with milk of lime and the material to be bonded. Briquettes are pressed from the mixture, placed on trucks and subjected to the action of hot steam at about 8 atms. pressure for 3 to 5 hours. A reaction takes place between the iron carbonate and the milk of lime, resulting in the production of crystalline calcium carbonate and a gelatinous ferrous hydrate which oxidises to ferric hydrate in the air. These two materials cement the particles of ore together. The addition amounts at the most to 10 per cent. ground spar and 5 per cent. slaked lime to 85 per cent. of the iron or other fine ore.

Naturally the method can only find application where there are available supplies of iron carbonates, such as spathic iron ore, clay iron-stone, or black band ore. Manganese carbonate can be substituted for iron carbonates. It is, therefore, applicable in almost all countries with the exception of America, Sweden, and Norway.

The reaction between spar and lime takes place with great ease, consequently a much shorter time of action of the superheated steam is required than in the quartz-meal lime method.

The advantages of this method compared with the quartz-meal lime method are as follows. No impurities from the smelting point of view, are introduced into the ore, the calcination necessary for the conversion of the iron carbonate into oxide is eliminated, and, further, any sulphur compounds (sulphides) existing in the ore are, under the combined action of the steam and lime, converted into calcium sulphide or sulphydrate and rendered innocuous in the smelting process. A disadvantage, however, is the low resistance of the briquettes in the fire.

An application of the method on a working scale is being carried out at the present time. The costs of briquetting have been worked out at 1·5 marks per ton.

(*b*) **Briquetting with Burnt Limestone** (quicklime, CaO). This binding material is unsuitable, since in the upper part of the shaft quicklime immediately saturates itself with water, or carbonic dioxide

in case of a deficiency of steam, develops heat, and causes overheating of the upper part of the furnace, while the lower part is cooled.

As a result, the numerous experiments on the use of quicklime, either alone or in combination with other materials, such as clay, ashes, hydrochloric acid,[1] blast-furnace slag, silicates, chlorides, or superheated steam, have been quite unsuccessful.

(*c*) **Slaked Lime** (calcium hydrate, $Ca(OH)_2$) has not proved successful unless subsequently converted into carbonate, since it must first lose its water in the blast furnace, when it again falls to powder, resulting in the disintegration of the briquettes.

Schumacher's Method for Manganese Ores

The finely crushed manganese ores are treated with 3 to 4 per cent slaked lime, and the briquettes obtained are heated to 100° C. or above In many cases the heating can be carried out with advantage in superheated steam. Insoluble manganates of lime are formed, and these materials cement together the particles of ore.

The process has not found practical application up to the present, but its costs need not amount to more than 1·5 marks per ton.

(*d*) **Briquetting with Plaster of Paris or Cement.**—Lime in the form of gypsum or cement cannot be applied with advantage Natural gypsum ($CaSO_4 2H_2O$) acquires, during heating at 200° C. (as a result of losing its water of crystallisation), the facility of reabsorbing water and setting-hard. The various natural and artificial cements behave in a similar way when treated with water. Such binding materials can produce very strong briquettes fulfilling all the demands made of such material until they arrive in the hotter zones of the furnace, when they lose their water content and disintegrate. Further, gypsum is not particularly suitable as a blast-furnace addition on account of its content of sulphur.

C. Koeniger's method (D.R.P. 135,141) also depends principally upon the binding power of gypsum and similar materials. In this process the fine ores or flue dust to be briquetted are first treated dry with lime (or magnesia) and **borax** in calculated quantities, and then with an aqueous solution of crude sulphuric acid of known strength. The material is then pressed to briquettes and allowed to dry in the air.

The use of sulphuric acid for the production of calcium or

[1] Hydrochloric acid would have a detrimental effect on the bell and downcomers of the blast furnaces

magnesium sulphate makes this process more suspicious than the use of mineral or burnt gypsum

(c) **Briquetting with Silicate of Lime.** In the following processes a silicate of lime is produced by certain additions and methods of treatment During its production and setting this material acts as a strengthener of the bond, and holds the bricks together, even at high temperatures, in the blast furnace

Schumacher's Quartz meal-Lime Method[1]

This method is generally similar to that discovered by Dr W. Schumacher of Osnabruck, and now widely used for the production of strong, high-quality building bricks from sand and limestone. In the production of lime sandstones an addition of 7 8 per cent chalk is made, but in the briquetting of ores 1 5 per cent. of finely ground quartz sand and 3-10 per cent quicklime are added, according to the special nature of the ores.

The method is carried out in three principal stages

(a) Preparation and mixing the raw materials

(b) Compression of the mixture to shape.

(c) Steam hardening the shapes to solid strong blocks

(a) The necessary quartz sand is usually ground to dust in a tube or ball mill, while the lumpy, unslaked lime (CaO) is first broken up in a stone breaker and ground fine in a ball mill.

The object of the fine grinding is to permit of the formation of silicate in stage 3 as evenly as possible throughout the mass

Part of the ground quicklime can be added to the sand to be ground, and the crushed materials are added to the fine ores to be briquetted in the previously determined correct proportions. The mixing or preparation machine made by Bruck, Kretschel & Co, illustrated and described in the next section, is used for thoroughly mixing the materials and slaking the lime.

The slaking consists in 100 parts by weight of lime absorbing 32 parts by weight of water, with the evolution of a considerable quantity of heat and the formation of calcium hydrate.

If the quantity of water necessary for slaking cannot be obtained from the moisture in the sand or ore it is added separately to the machine.

[1] *Stahl und Eisen*, No. 1, p 7, 1906, and No. 10, p 321, 1908.

(*b*) The properly prepared mixture is compressed in a suitable briquette press to blocks which are laid on a special hardening truck.

(*c*) The trucks are driven into the so-called hardening boiler, and subjected to the action of superheated steam at about 8 atms. (174° C.), for 10–12 hours, when the quartz-meal combines with the lime with the evolution of heat and the production of artificial Wollastonite, which completely strengthens the briquettes. This silicate of lime is not affected by moisture, and is not decomposed below its melting point. When withdrawn from the hardening kettle the briquettes are ready for immediate smelting.

According to Dr Schumacher, the method is applicable to all kinds of fine iron ores unsuitable for immediate smelting. Such include powdery brown iron ores, purple ores, magnetic concentrates, and flue dust.

Application on the large Scale. A typical two-press plant, outlined by Bruck, Kretschel & Co. of Osnabruck, is illustrated and described in the later section on Complete Briquetting Plants. Up to the present two plants have been laid down and are in operation—at the Kongshutte for the briquetting of purple ore with addition at the present time of iron-rich flue dust and Gellivara magnetic iron ore slimes and also at Krupp's Friedrich-Alfred Hutte in Rheinhausen for the briquetting of flue dust.

At the Kongshutte the briquettes are usually made up of 91 per cent. purple ore, 4–5 per cent quicklime, and 3–4 per cent quartz-meal; with Gellivara slimes and similar ores, an addition of 3 per cent. lime and 2 per cent. quartz-meal is sufficient to obtain high strength. Further details of the Kongshutte briquette factory, and the success of the method there employed, is given in the section on Complete Briquetting Plants at the conclusion of the description of the typical two-press plant mentioned above.

At Rheinhausen up to 22,000 briquettes, each of 4 kgs weight (equal to a total of 88 tons), are produced by two presses in a 10 hour shift from 85 per cent. flue dust, 10 per cent. quicklime, and 5 per cent quartz-meal. They contain 32–38 per cent. iron, and on ignition lose about 15 per cent (coke, carbon dioxide, and water). After several years' working and modifying experiments the method was abandoned in 1909, and replaced by a process more suitable to the prevailing local conditions.

The cost of installation of a two-press factory working the quartz-meal-lime process with an output of 40,000–44,000 briquettes per day and night shift (10 hours each) have been given as about 220,000 M.[1]

[1] *Stahl und Eisen*, No. 10, p. 322, 1908.

The yearly output in tons naturally varies with the specific gravity of the ores utilised.

In the following table[1] the cost of briquetting, quantities, weights and total yearly outputs are given for three typical cases, viz. flue dust, purple ore, and Gellivara slimes:—

Material Briquetted	Briquettes per 24 hr.	Weight of each Briquette	Yearly (300 days) Output	Cost of Briquetting per ton
		kgs.	tons	M.
Flue Dust	40,000	5	60,000	3.11
Purple Ore	40,000	6.5	78,000	2.926
Gellivara Slimes	44,000	8	105,600	1.53

This table has been drawn up on the basis of adding quicklime and quartz sand to the various ores in the percentages outlined above on prices of 12 marks per ton for quicklime and 3 marks per ton for quartz sand, wages of 4 marks per 10 hours' shift, a sinking fund of 8 per cent. on the total costs of installation (220,000 marks), and the costs of power, steam, repairs and sundry materials have been ascertained during the working.

With special reference to the quartz meal, this material costs about 7 marks per ton, inclusive of liquidation, power, costs, and wages,[2] assuming that the quartz sand costs 3 to 3.75 marks per ton. An addition of 5 per cent. therefore (the highest amount which has been used up to the present) costs about 0.35 mark per ton of briquettes.

German Briquetting Company's Method[3]

(For fine ores or flue dust.)

In the method used by the Deutschen Brikettierungsgesellschaft m. b. H. of Altenkirchen-Westerwald primary regard is paid to the blast furnace itself, inasmuch as everything which is likely to be detrimental to its operation in any way is avoided.

Generally speaking, the fine ore or flue dust is only treated with some form of lime which, as a result of its composition and admixture with other materials, guarantees a perfectly strong structure to the briquettes even at a red heat.

The composition and amount of bond added depends on the nature of the materials to be briquetted, but the addition seldom exceeds 10 per cent. The main object is the formation of a silicate of lime which

[1] *Stahl und Eisen*, No. 10, p. 322, 1908.
[2] *Ibid.*, p. 321, 1908.
[3] *Ibid.*, pp. 323–324.

hardens in the cold, does not disintegrate at a moderate heat, and sinters at a higher temperature.

Fine ores or flue dust are mixed with a binding material devised by the company, pressed to a suitable shape, and the briquettes allowed to stand for 3 or 4 weeks without further treatment. They are then ready for smelting.

Application of the Method.—During a test made on the large scale at Bremerhutte, about 90,000 kgs. of these briquettes were used in 3 days for the manufacture of spiegeleisen. The results of working were much more satisfactory than any previously obtained; the charge was more open, and the dust in the flue gases was diminished by about 50 per cent. The output of iron, formerly 70 tons in 24 hours, rose to 77, 80, and 77 tons in the three double shifts during which briquettes were employed. The coke consumption, 1411 and 1465 kgs. respectively per ton of pig iron, in the previous two days fell at the same time to 1332, 1330, and 1380 kgs. per ton of iron produced.

Application on the working scale has been put in hand by the Sieg-Rheinischen Huttenaktiengesellschaft at Friedrich-Wilhelmshutte on the Siegerland calcined spathic iron ores. The installation, which is said to be working quite satisfactorily, is sketched and briefly described in the section on Complete Plants

4. Briquetting with Slags or Water-glass

Many proposals have been made in this field. Above all, attempts have been made to utilise the blast-furnace slags available free of charge at blast-furnace plants.

Blast furnace slags consist of compounds of the gangue in the smelted ore with the additions and the fuel ash, they consist mainly of silicates of alumina and lime, often mixed with magnesia and manganous oxide. During good working they contain only small quantities of ferrous or ferric oxides. Alkalies are never absent, and sulphides of the alkaline earths and manganese seldom, while various other materials form secondary constituents. The silica content is usually not simple, generally pointing to a mixture of mono- and bisilicates. Coke furnace slags usually approximate to monosilicates, charcoal furnace slags to bisilicates. (Wedding.)

Use of Cold Blast Furnace Slag.—Cold slags have been ground, mixed with the ores to be briquetted, and the mixture compressed, with the expectation that the slag would soon melt in the furnace and act as a bond. However, the fact that the melting point of the slag was

much too high to prevent the briquettes falling to pieces again was not taken into account

A preliminary sintering of such briquettes, with the object of strengthening them also appeared to be unsuitable, since in this case, such a large quantity of slag was required that the iron content of the briquettes was diminished far too much. Application of molten slag has also been tried by stirring iron ore into the slag in the neighbourhood of the slag hole. It was, however, found that the slag solidified before it had taken up very much of the ore.

The method of the Scoria Company[1] (for flue dust and powdery ores) is, however, worthy of special consideration. Originally, the method of the Scoria G. m. b. H. of Dortmund,[2] according to the patents of Oberschulte (D.R.P. 138,312) and Mathesius (D.R.P. 164,536) subsequently extended by subsidiary and foreign patents, depended on the application of basic blast-furnace slag (slag sand) granulated by means of steam under pressure as binding material, and hardening of the moulded blocks in superheated steam.[3]

Steamed blast-furnace slag, a dry cement-like powder with a protective action against moisture, possesses under these conditions, the same binding power as good Portland cement. The bonding power depends upon the formation of hydrated silicates, and is consequently destroyed by expulsion of moisture on heating the briquettes to about 1000° C. in the blast furnace, just as in the case of the use of Portland cement and other silicates. This bonding power can only be replaced by sintering at a higher temperature. Application of blast-furnace slag provides the advantage that this material sinters at about 1000° C. Consequently only the nature of the bonding action changes at 1000° C., *i.e.* the hydrated silicate bonding is substituted by sintering, and the strength of the briquettes is not impaired. An addition of 8 to 10 per cent. of a suitable blast-furnace slag is sufficient to produce briquettes of ample strength. Recently, however, it has been decided to replace about half of the slag addition by lime.

Mode of Operation of the Process.—Granulated blast-furnace slag is treated with superheated steam in a revolving drum or other suitable vessel. It is then thoroughly mixed with the quicklime and material

[1] *Stahl und Eisen*, No. 10, pp. 324–325, 1908; *Z. Berg- u. Huttenm. Rundschau*, No. 14, pp. 183–184, 1906. Printed prospectus of the Scoria Company.

[2] H. Schulze-Steinberg, Duren, near Stockum i. W., and W. Mathesius, Professor of Metallurgy at the Kgl. Techn. Hochschule, Berlin. Manager, Carl Meyer, Dortmund.

[3] The Scoria Company has also developed this method for the production of building blocks (slag stones) from blast-furnace slag (see special prospectus).

to be briquetted in an edge-runner mill The blocks pressed from this mixture are converted into porous briquettes ready for smelting by a 10 hours' heating in a hardening kettle, just in the same way as lime sandstones are treated. With certain ores only reduced with difficulty, such as pulverised magnetic iron ore or chrome iron ore, it is advisable to add a certain percentage of coke or coal powder to the mixture.

Briquetting costs, using exclusively cheap blast furnace slag, vary, according to the specific gravity of the material, between 0·8 and 1·4 marks per ton, averaging about 1·1 marks. Partial replacement of the slag with lime makes the costs correspondingly higher. A two-press plant is illustrated and described in the section on Complete Plants, and a complete statement of costs is appended.

The process was started on a working scale at Krupp's Friedrich-Alfred Hutte, Rheinhausen, in the year 1909, but the results of working have not yet been published. Chemical analyses of four Scoria briquettes prepared some years ago are given in the table below[1]:—

Content of	I. Gellivara Ore	II. Mixture of Flue Dust and Purple Ore.	III Burnt Pyrites	IV Flue Dust
	per cent.	per cent.	per cent	per cent
Fe	55·10	44·10	49·05	43·75
Fe_2O_3	79·20	63·00	70·10	62·50
CaO	6·22	7·52	7·20	11·18
SiO_2	8·91	20·18	9·52	9·95

The proposals to apply basic slag, and later water-glass, with or without asbestos, and subsequent treatment with steam, have not attained practical importance Basic slag and water-glass are much too valuable materials to be used with economical success in the binding of ores, even when such a slight amount is necessary as is actually required.

5. Briquetting with Kieselguhr, Carnallite, and Molasses.

Such a method, in which the materials applied are partly inorganic and partly organic, is represented by *Dr F. W. Dunkelberg's Method* for flue dust, pulverised iron ores, burnt pyrites, and the like. This

[1] *Z. Berg- u. Huttenm. Rundschau*, No. 14, p 184, 1906

method, discovered by Professor F. W. Dunkelberg[1] of Wiesbaden consists in mixing intimately 100 parts of the crude material with 2 parts kieselguhr, 0·4 part carnallite, and 1 part molasses, pressing the mixture to blocks, which are then roasted or sintered at 1000° C. in ring furnaces.

Kieselguhr, or infusorial earth, consists principally of a deposit of the shells of diatoms composed of pure silica. It finds very wide application, for example, in aniline manufacture, the production of cements, fire-proof stones, and so on.

Carnallite, one of the most widely distributed of the potash salts, consists, when pure, of $KCl,MgCl_2,6H_2O$, and is used on the large scale chiefly for the production of potassium chloride for use as a manure. For the present purpose it is used mainly on account of its magnesium chloride content, which is specially suitable for application to flue dust on account of its action as a catalytic agent. The potassium salt, however, exerts a detrimental effect on the furnace lining.

Molasses, a cheap waste product of sugar manufacture, is rich in sugar and gummy compounds, and has already been recommended as a binding material for coal smalls; it does not, however, contain any moisture (see Vol. I. p. 57). During calcination in the Dunkelberg method the sugar is carbonised and coked.

The sintering is carried out in modern brickmaking ring ovens, which often exist at many metallurgical works for constructional purposes. By this means the briquetting is carried on much cheaper.

The method first found practical application at the colour works of Meister, Lucius & Brüning at Hoechst am Main, for briquetting the iron-rich aniline residues and lixiviated burnt pyrites.

It was at first necessary to sell not inconsiderable quantities of such residues at values far below the current ore values. At the present time, however, these materials are briquetted and sintered with considerable success by the above method. The mixers and presses of the Rixdorfer Maschinenfabrik in Berlin are used for mixing and compressing the materials. It has been shown that the powdered ore is much more easily worked than the damp, sticky clay, and the subsequent sintering in the modern ring furnaces is much cheaper than in the case of clay bricks, since iron oxide has a much lower specific heat than that of clay, a property which leads to more rapid heating, reduction by carbon monoxide, and cooling.

The colour-work briquettes contain 66 per cent. Fe, and have a specific gravity of 4·05. 200 tons of briquettes are obtained daily from 50 cubic metres of raw material. Costs of production amount to about 1 M. per ton, but by increasing the amount of material worked

[1] Dr F. W. Dunkelberg, "Ein Beitrag zur Brikettierungsfrage" (*Stahl und Eisen*, No. 15, pp. 551–552, 1909); "Das Brikettieren von Gichtstaub" (*Z. Erz Bergbau*, No. 7, pp. 138–140, 1909).

upon to 70 cubic metres per day, they could be reduced to 80 pf. per ton.

Application of the Method to Flue Dust.

Professor Dunkelberg has made the following calculations for the special conditions prevailing at two ironworks in the Minette district of Lorraine:—

EXAMPLE I.—Iron works No. 1 produces daily 70–80 tons of flue dust, having a specific gravity of 1·4. Consequently $\frac{70}{1 \cdot 4}$ to $\frac{80}{1 \cdot 4} = 50$–$60$ cubic metres have to be converted into briquettes daily.

The composition of the dust in the various dust chambers varies considerably, according to the nature of the ores, the working of the furnace, and so on. In the first chamber, about 80–85 per cent. of the dust is collected, and contains from 34 to 36 per cent. Fe.

The metal value of 1 ton dust reckoned on the usual market prices (Fe = 30 pf., Mn = 55 pf., and residue = 10 pf.) works out as follows:—

Fe	$= 35 \cdot 0 \times 0 \cdot 30 =$	10·5 M.
Mn	$= 1 \cdot 6 \times 0 \cdot 55 =$	0·88 ,,
Residue	$= 19 \cdot 0 \times 0 \cdot 10 =$	1·90 ,,
Total		= 13·28 M.

50 cubic metres = 70 tons of flue dust would therefore have a metallurgical value of $70 \times 13 \cdot 28 = 930$ M.

Dunkelberg estimates the cost of briquetting of 50 cubic metres flue dust at an extraordinarily low figure, thus:—

A.—Costs of Plant (without land, buildings, and calcining furnaces).

Mixer No. 3	1600 M.
Press No. 7	3640 ,,
Foundations	360 ,,
Total *A*. . . .	5600 M.

B.—Daily Working Costs (at 300 working days (of 10 hours each) per annum).

I. *Production of Compressed Blocks.*

(*a*) Depreciation and interest (15 per cent. on 5600 M.) = . 2·80 M.

(*b*) Addition of binding material:—

500 Ztr. molasses at 6 pf. =	30·00 M.
12·50 kgs. carnallite at 4 pf. =	0·50 ,,
25 ,, ,, 1·2 pf. =	0·30 ,,

Total . . . . . 30·80 M.

(c) Wages :

2 foremen at 5 M	10·00 M	
5 youths at 3 M. . .	15·00 „	
Total . .		25·00 M
(d) Power (about 25 H.P. at 4 pf. per H.P. hour) 25 × 10 × 4		10·00 „
(e) Lubrication and repairs (7 per cent. on 5600 M.)		1·40
Total I.		70·00 M

II. *Sintering the Pressed Blocks*

(f) Depreciation		
The cost of installation of a ring oven with 14 chambers amounts to about 50,000 marks, so that writing off 5 per cent. per annum gives a daily share of $\frac{50,000}{20 \times 300}$		8·33 M
(g) Coal consumption (nuts)		40·00
(h) Wages		
2 firemen at 5 M	10 M	
3 handlers at 3 M	9 „	
Total . .		19·00 „
Grand total II.		67·33 M

Synopsis.

Total I (preparation of pressed blocks) . .	70·00 M.
Total II (sintering „ „)	67·33 „
Total daily briquetting costs, total *B*.	137·33 M.

Approximately 140 M., which corresponds to $\frac{140}{70} = 2$ M. per ton.

EXAMPLE II.—At the second iron works the flue dust contained 45 per cent. Fe, a considerably higher proportion than in the previous case. The metallurgical value of a ton of dust is increased correspondingly, *i.e.* to 15·83 M., as against 13·28 M.

The quantity of dust recovered daily is 100 tons, or 30,000 tons per annum, so that the metallurgical value of the dust is 15·83 × 30,000 = 474,900 M. per annum. To briquette this costs 200 M. daily = 60,000 M. yearly, so that by briquetting the whole of the flue dust an annual

profit of 400 000 M can be obtained. It is of still greater advantage (see p. 9) to briquette flue dust with the specifically heavier powdered ore.

B. BRIQUETTING WITH ORGANIC BINDING MATERIALS

It is only natural to attempt to utilise for binding fine ores such organic bonds as have been successful in coal briquetting. Although in this case the final object and requirements are vastly different, organic materials are regarded as suitable for the production of briquettes for smelting purposes, since they not only act as binding materials, but also as heat producers and reducing agents, so that economies may be expected in the coke consumption, while at the same time there is no question of impoverishing the charge. Whether, and the degree to which economical advantages can be attained is determined by the price, the quantity which it is necessary to add, and the special properties of the organic material used, more particularly with regard to its behaviour at the higher temperatures in the blast furnace and the nature of its reducing effect on the ore.

The price of the suggested organic binding materials is generally higher, and in some cases much higher, than that of most of the inorganic binding materials, but this does not necessarily exclude their use. If, however, untimely fusion, combustion, or volatilisation takes place in the blast furnace, bringing about or hastening disintegration of the briquettes, the material is at once stamped as unsuitable. With regard to the reducing action of organic binding materials, it must be remarked that as a result of the intimate mixture with the particles of ore this usually takes place directly (by carbon), while the blast furnaceman invariably strives after the much more favourable indirect reduction by means of CO gas.

The first volume of this book (pp. 39–60) should be consulted with regard to the properties of the organic binding materials indicated in the table on pp. 29–32. Further information, however, is given below with regard to cell pitch in the light of more recent knowledge.

1. Briquetting with Pit Coal or other Varieties of Coal.

As far back as the middle of the nineteenth century attempts were made to produce the so-called "metal coke" by mixing iron or manganese ore with a caking coal and coking the mixture in a coke oven. However, even when the ores were successfully bonded in this

way and the product held up well in the blast furnace the amount of ore which could be added to the coal was much too small. Further, good coke is far too valuable a product to be sophisticated by admixture with foreign materials.

In 1865 Wedding proposed to use brown coal containing paraffins but the process proved unsuccessful.

2. Briquetting with Coal, Tar, Pitch, Asphalt, Petroleum (Masut), Dried Blood

J. Rudolphs and J. Landin's Method (D.R.P. No. 104 669)[1] with coal and tar

In this method the fine ores are mixed with pulverised pit coal or anthracite, finely divided animal charcoal and liquid or solid materials containing heavy hydrocarbons, such as coal tar, etc. The mixture compressed into lumps or briquettes is heated at 300° to 500° C. under pressure. After quite a short time a sintered mass is obtained which after cooling forms a dense material with a glassy surface (this, however, is not of advantage, see p. 14, No. 2) capable of resisting the effects of heat and moisture.

In the case of magnetic iron ore containing about 87 per cent. Fe_3O_4 or 63 per cent. Fe, 1000 kgs. of ore are mixed with 150 kgs. finely divided anthracite, 50 kgs. animal charcoal rich in nitrogenous material, and 60 kgs. heavy coal tar when it is desired to produce iron containing about 10 per cent. carbon. After heating to about 450° C. there is present sufficient carbon left in the briquettes or blocks to reduce the ore and carbonise the iron. The inventors have prepared such briquettes and reduced them by heating to a high temperature in a naphtha furnace.

The method has found application on the large scale since the beginning of this century for the production of iron at various places in Sweden in spite of the relatively high cost of the additions. Working results cannot be given.

The inventors have also modified their process for the briquetting of bauxite in the aluminium industry, and for briquetting calamine or roasted blende in the zinc industry. Dried blood, which is specified among other materials, is too costly for actual use in practice.

For the production of aluminium, clay is mixed with a hydrocarbon nitrogenous material, such as blood charcoal or nitrogenous tar. With bauxite the mixture is so proportioned that the carbon added corresponds to the oxygen

[1] *Zeit. f. Angew. Chemie*, 1899.

content of the crude clay material. A typical example is 100 kgs. finely divided clay, 25 kgs. finely divided anthracite, 10 kgs. coal tar, and 5 kgs. dried blood. After thoroughly mixing the mass is compressed to briquettes and heated as above, the products of distillation being burned. The sintered briquettes are then introduced between the electrodes of an electric furnace and reduced to metallic aluminium. A similar method is employed in the production of zinc from galmei or roasted blende. The ore is pulverised and mixed with anthracite, tar, and dried blood in the proportions already given above for aluminium, in such a way that the carbon content is sufficient for the reduction of the zinc. The mixture is then pressed, heated, and reduced in an electric furnace.

W. Hüttelmann's Method (D.R.P. No. 147,312) with pitch and coke or charcoal.

The fine iron ores are first mixed with small coke or charcoal, and the mixture is freed from possible moisture by drying in suitable appliances. The dried material is worked up with hot hard pitch in such a way that each particle of ore, coke, or charcoal becomes coated with a thin skin of this material. The mixture is then pressed into briquettes, which after cooling are very strong and ready for charging into the blast furnace.

Fig. 2 (p. 20) shows a flue-dust briquette made by this method with 6 per cent. pitch (No. 9), while a fracture of the same material is also illustrated (No. 10).

In the fire the briquettes do not disintegrate, but fuse up slowly.

For iron ores the maximum addition of small coke amounts to about 50 per cent., and of pitch to 6 per cent. of the weight of the finished briquette. The costs of this expensive binding material are, under certain conditions, more than compensated for by the increase in value of the small coke, which serves as a substitute for the large coke, otherwise necessary for reduction. In view of the large amount of small coke required, the blast-furnace plant should be connected with one or more coking plants to fill the necessary requirements at a low cost. These conditions are not always easy to fulfil. The statement of costs below gives a further insight into the profits to be derived from the method.

COSTS OF PRODUCTION OF 150 TONS IRON ORE BRIQUETTES IN TWELVE HOURS

(a) Wages

4 men supplying ore and small coke, at 4 M.	16 M.
2 " heating the drying appliances,[1] at 4 M.	8 "
(A removal of 20–25 per cent. moisture is assumed.)	
2 " on the steam pitch heater, at 4 M.	8 "
1 man on the pitch distributer, at 4 M.	4 "
1 " " elevator, at 3.50 M.	3.50 "
2 men " kneading plant and worm conveyor, at 3.50 M.	7 "
2 " " briquette presses, at 3.50 M.	7 "
4 " " band conveyors and shunting ore waggons, at 3 M.	12 "
1 mechanic, at 4.50 M.	4.50 "
1 foreman or manager, at 5 M.	5 "
Total	75.00 M.

Consequently the labour costs per ton of briquettes $\frac{75}{150}$ = 0.50 "

(b) *Hard Pitch*

At the most, 6 per cent. = 9 tons are required, which, at a price of 45 M. per ton (reckoned high), costs . . . 405 "

(c) *Power*

The plant requires 85 H.P., which, at 0.4 pf. per H.P. hour, works out for 10 hours at . . . 34 "

Total for labour, pitch, and power . . . 514 M.

(d) *Materials.*

To this must be added the costs of such materials as oil, cleaning material, repairs and replacements. Unfortunately these costs are not given, but cannot amount to more than . . . 14 "

(e) *Sinking Fund and Interest on the Cost of Installation*

Neither are these figures given. The cost of installation can be estimated at about 150,000 M., and an annual allowance 15 per cent. per year of 600 shifts works out per shift to . . . 38 "

Grand Total . . . 566 M.

Or $\frac{566}{150}$ = 3.70 M. per ton of briquettes.

On the grounds given above, the cost of the coke smalls are not included in this estimate.

The increase in value of the small coke is determined by the difference

[1] The drying plant is heated by furnace gases, which entails no further cost.

in price between lumps and smalls Good lump coke costs about 150–165 M per double load (10 tons), the same quantity of smalls costing only 9–12 M If, therefore, 50 per cent smalls is treated, the maximum value of the quantity worked up per shift (75 tons) cannot amount to more than 75 × 1·2 = 90 M On account of its appreciably higher ash content, however, it cannot be credited with the full value of the lump coke which would otherwise be required for the ore reduction, but is only credited with a value of, say, 120 M per double load, yielding a total value of 75 × 12 = 900 M In this way a difference in value of 900 − 90 = 810 M is obtained, representing a saving equal in value to this amount This is diminished by the costs of briquetting, so that it amounts to 810 − 566 = 244 M

Again, the increase in value of the fine ore must also be taken into consideration If this be taken as only 2 M per ton, the total increase in value amounts to 150 M, so that the profits of briquetting are 244 + 150 = 394 M, or approximately 400 M per shift From this it is obvious that a profit is assured by this process even with a pitch addition of somewhat higher than 6 per cent, or a pitch price higher than 15 M.

In the above calculations no account has been taken of the higher heat consumption in the smelting of these small coke pitch briquettes, brought about by the direct reduction with carbon

The process, using steam kneaders and toggle-joint presses, has found application on a working scale at various smelting plants in Lower Rhenish Westphalia. The results do not appear to have realised expectations, since the method has now been abandoned to some extent, principally on account of the properties of hard pitch, which is less suitable for ores than the recently introduced cell pitch

It is not known that Wedding's proposal to use asphalt or petroleum residues (Masut) for the briquetting of flue dust has ever been introduced into practice, but in any case it can only be considered for conditions under which these valuable materials can be obtained sufficiently cheaply

3 Briquetting with Cell Pitch

A GENERAL

Cell pitch is obtained from cellulose liquors (sulphite cellulose liquors). A brief account of the suitability of this liquor and the cell pitch for use as a binding material in briquetting has already been dealt with in Vol I pp 57–59 Since, however, the production and utilisation of cell pitch has been considerably improved of recent years, it has become of ever-increasing importance in the briquetting of pit coal, hard brown coal, coke dust, flue dust, and fine ores. It seems, therefore, to be desirable to extend and amplify the information

given in Vol. I. and to describe the state of affairs existing at the present time.

(a) Origin of Cell Pitch

In all civilised countries cellulose factories are more or less widely distributed. They are often to be found on navigable rivers and always closely situated to railway lines. Waste liquors hitherto regarded at cellulose factories as a valueless and often troublesome waste product, can always be obtained at a very low cost.

According to the estimate of Sachkenkern, the raw material for the production of about 500,000 tons of cell pitch has been run to waste in the rivers of Germany alone up to the present time.

The waste liquors (diluted liquors) contain 90 per cent. water and 10 per cent. solid material which subsequently becomes cell pitch. As a result there is always a quantity of cell pitch to be obtained equal to the cellulose output of a factory. It can be taken that the minimum cellulose output of a factory is about two double loads (20 tons) daily, which since work is carried on day and night works out at 7000 tons per year. Most factories however produce far larger quantities.

The total production of cellulose and therefore of cell pitch may be estimated at about 450,000 tons yearly.

Similar quantities may be taken into consideration for Austria-Hungary, America, Sweden and Norway. Consequently the quantities of material available for the production of cell pitch are so great that a sufficient amount of this binding material will be available for all conceivable time even leaving out of consideration the fact that the production of cellulose steadily and continually increases.

In Germany favourable agreements have already been concluded with cellulose factories for a long period of years.

(b) Production of Cell Pitch

It is always highly desirable to build a projected cell pitch factory in close proximity to a cellulose factory, since the crude liquors can then be transported directly through pipes or in some other suitable manner.

In the first place, it is necessary to remove sulphur compounds, more especially sulphurous acid from, and if necessary to neutralise the liquors, which are then evaporated to a syrupy consistency and brought into the solid state.

The production of cell pitch is worked continuously, so that the working year contains at least 350 working days The power consumption is somewhat high, generally speaking, however, the steam needed is covered by the amount of waste steam from the cellulose factory under favourable conditions Special patented appliances are used for evaporating the water, concentrating to a syrup, and solidifying the product, which is ready for application or transport as it is produced

Transport is effected in covered waggons without special packing. Hitherto the freight costs in Germany have been based upon the coal tariff, so that the costs of transport are very moderate.

The costs of installation of a cell-pitch factory for a daily output of 30 tons cell pitch, inclusive of land, foundations, buildings, railway connections, etc, amount to about 500,000 M.

The first and chief cell pitch factory in Germany was erected at Walsum on the Rhine in connection with the local cellulose factory of the "Maschinenpapier-Aktiengesellschaft Aschaffenburg." Here the "Vereinigten Gewerkschaften Eduard und Pionier," with head offices in Walsum, carry on the production of binding materials from the waste liquors of the manufacture of cellulose by Dr Tramer's patent process owned by the "Gewerkschaft Eduard (Frankfurt a. M)" of Langen in the Darmstadt district.

The first licensee under this patent was the "Gewerkschaft Pionier" of Walsum a. Rh, who subsequently formed a company for the joint ownership and working of the process under the above name "Cell pitch" (*Zellpech*) is a name protected by the Gewerkschaft Eduard for binding materials prepared from the waste liquors.

With its present equipment, the factory at Walsum produces 20 tons cell pitch daily, but, since the demand is continually increasing, the plant will shortly be extended until the output can be doubled

The price of the pitch produced amounts to 40 M per ton, so that it is approximately as costly as coal-tar pitch (see Vol. I, p. 53 and p. 262).

(*c*) *Properties of Cell Pitch.*

As a waste product of the production of cellulose by a chemical treatment of wood chips, cell pitch is made up of the whole of the incrustations, resins, etc, of the wood which have been converted during the process into a new kind of substance not yet classified chemically. In external appearance it is brown and similar to resin, it is also strong and brittle (fig. 7). A series of analyses gives as its average composition:—

78 per cent. combustible organic substances
10 ,, water.
12 ,, ash

The following properties of cell pitch are of special advantage in the briquetting of coals and ores:—

1. Great adhesive properties and binding power so that a small quantity suffices for bonding (average addition of 5 per cent. against 5–10 per cent. of coal tar pitch). For many kinds of coal and fine ores even as little as 2 or 3 per cent. is sufficient.

2. It burns without smoke, a factor of special advantage for domestic purposes, for factories in and near towns, for railways etc. and also for ships, particularly battleships and liners.

3. Cell pitch is readily worked up and can be ground up even when hot; further, it is possible to produce it initially in the form of a powder, when it can then be worked up without previous grinding.

4. Cell pitch dust exerts no corrosive and other effects injurious to health, and does not therefore cause trouble to the workers.

5. Cell pitch neither softens nor volatilises when heated as many coal tar pitches do; it cokes before combustion sets in, and causes the briquette to stand up well in the fire and not crush under the load. It burns gradually, and leaves nothing but its content of ash.

The less advantageous or disadvantageous properties of cell pitch are:—

6. A not inconsiderable content of water and ash (10 and 12 per cent. respectively).

7. Low calorific value (only about one half that of coal tar pitch). This moderate heating power is, however, completely utilised as a result of good behaviour in the fire (see 5), which is often not the case with coal-tar pitch.

8. Solubility in water as a result of its origin from waste liquors. As a result the stability of the briquettes against water and weather is only slight, and it becomes necessary under certain conditions to treat the briquettes to make them more stable, thus giving rise to added costs.

In general, treatment of the briquettes is only necessary when they have to be stored in the open for a long period and maintained in a faultless condition. But for many purposes, cell pitch briquettes which have not been specially treated are sufficiently weather resistant. If a stock of such briquettes is exposed to all weathers for a long time the outer layer of the briquettes is attacked, while the inner portion is to all intents and purposes

unaffected. Further, it has been shown that cell pitch briquettes softened by heavy rains do not disintegrate, and that they regain their hardness and strength after thorough drying.

Cell pitch briquettes have approximately the same weather-resisting properties as ordinary brown coal briquettes.

9. High price, almost equal to that of coal tar pitch. This disadvantage is, however, diminished by the fact that it is only necessary to use a smaller quantity (see above, 1).

These unfavourable properties of cell pitch do not affect its value to such an extent that it cannot enter into successful competition with coal tar pitch and other binding materials in a large number of cases because of its special advantages. In any case, it forms a welcome addition to coal tar pitch. From the foregoing it is seen that cell pitch can be applied with advantage to the briquetting of the following crude materials:—

1. Smalls of anthracite, flaming and hard brown coals.
2. Coke dust from pit and brown coals.
2. Fine ores (surface ores, powdery brown-iron ores, manganese ores, burnt pyrites, purple ore, etc.).
4. Flue dust.

Cell pitch can also be applied with advantage as a binding material for all kinds of coals and other raw materials.

B. APPLICATION OF CELL PITCH TO COAL AND COKE BRIQUETTING.

(a) *Method of Briquetting.*

At the present time coal and coke briquetting is carried out in the best possible manner by Hengstenberg & Banzenberg of Ruhrort, who have built a new briquette factory dealing only with cell pitch as bond. The material briquetted is principally coke dross, alone or in admixture with anthracite and fat coal. A pit coal briquette factory of similar size, in which the Langenbrahm mine is largely interested, also uses cell pitch, and has been built in the Ruhr district by the same company.

For the production of cell-pitch briquettes the usual appliances for briquetting with coal-tar pitch are generally employed. A thorough admixture of binding and briquetting materials is of primary importance. Large briquettes are subjected to a much higher pressure than the ordinary ones, the compression being carried out by means of a powerfully built Tigler press working at 500–600 kgs. per sq. cm. of surface compressed.

For smaller briquettes, much lower pressures are used. Egg briquettes made with cell pitch can be prepared by the same presses in which coal tar pitch briquettes of similar shape are made. Sundry cubicle and egg briquettes are illustrated in fig. 7 (2. 15) p. 26.

(b) *Treatment of Cell Pitch Briquettes to attain Stability against Water and Weather*

If it is desired to obtain this property (p. 14, No. 1), choice must be made between a subsequent heating of the pressed blocks and a preliminary chemical treatment of the briquetting material.

Subsequent heating (by hot air, waste heat, flue gases, etc.) is the older method, and by a partial coking of the cell pitch makes the briquettes resist the action of water and weather completely. At the same time it roughens their surfaces and makes them very hard and strong. In many cases the process can be carried out very economically, especially if there is available a cheap source of heat and the briquettes can be moved about mechanically.

In this connection, only one example of an iron works can be given here. Situated in Russia, it had formerly dealt with coke from Austrian and German Silesia, although it possesses its own coal pits, which do not, however, yield good coking coal. This coal is now coked and yields only coke dross, which is briquetted with cell pitch. The briquettes are then heated by means of blast furnace gases to about 300° C., and yield a product capable of resisting all weathering effects.

The recently discovered process of rendering cell pitch briquettes quite insoluble in water by pure chemical means, consists in the addition of certain chemicals (still kept secret) to the mixture before pressing. At the present time this method obviously raises the costs of producing the briquettes by a not inconsiderable amount, probably by 1·5 M. per ton of finished briquettes. This increase in price, however, might be considerably diminished if the chemicals were used in much larger quantities and, as a result, obtained at a lower rate.

(c) *Various Grades of Cell Pitch Fuel Briquettes*

Cell-pitch anthracite briquettes could very well replace the more costly anthracite nuts with advantage because of their smokeless and odourless combustion. Cell pitch coke briquettes may serve as a substitute for domestic coke and the lump coke used in blast furnaces and cupolas. In the broken state they can be substituted for the best broken coke used in central heating stoves.

Cell-pitch coke briquettes burn with some difficulty unless sufficient draught is provided. For some purposes this is of distinct advantage, since slow combustion is bound up with great heat efficiency. When slow burning is disadvantageous, mixed briquettes of coke dust and fat coal are produced. Those properties of fat coal, considered troublesome and disastrous in many kinds of firing, completely disappear when mixed with coke in cell-pitch briquettes, while at the same time the briquettes are made to burn more easily.

Coke dross—anthracite—and even coke-anthracite cell-pitch briquettes have given every satisfaction when applied in suction gas producers. It has also been found possible to prepare good mixed briquettes which burn uniformly from various kinds of coal, such as pit coals and brown coals.

(d) *Installation and Production Costs*

The costs of installation of a two press factory for an hourly output of 5 tons and a yearly production of up to 60,000 tons are made up somewhat as follows:[1]

Land	30,000 M.
Buildings (incl. of foundations and chimney)	50,000 ,,
Machinery, power, lighting, etc	175,000 ,,
Tools, etc.	10,000 ,,
Railway sidings	25,000 ,,
Miscellaneous requirements	5,000 ,,
Total	295,000 M.

The costs of production, including the cell-pitch, but exclusive of the raw material briquetted, at a yearly production of 60,000 tons, amount to per ton of briquettes.—

With a 4 per cent. pitch addition	3 M.
,, 4½ ,, ,, ,,	3·20 ,,
,, 5 ,, ,, ,,	3·40 ,,
,, 5½ ,, ,, ,,	3·60 ,,
,, 6 ,, ,, ,,	3·80 ,,
,, 6½ ,, ,, ,,	4 ,,
,, 7 ,, ,, ,,	4·20 ,,
,, 7½ ,, ,, ,,	4·40 ,,
,, 8 ,, ,, ,,	4·60 ,,

[1] According to a cost sheet prepared for a German works

The costs of the subsequent treatment, with the object of attaining damp-proof briquettes, must be considered specially from case to case as required. At the present time they are to be estimated at a maximum as 1.50 M. per ton. To these briquetting costs and costs of subsequent treatment must be added the costs of the crude coal and the royalties.

The royalties can be provided for either in fixing the price of the cell pitch, or by a fee to be paid for each ton of briquettes produced. In Germany it is customary to take as a basis for royalties a fee of 1 M. per ton of briquettes. In the acquisition of the rights for all lands, districts, and foreign countries the Gewerkschaft Eduard have reserved to themselves the right of making special agreements.

C. *APPLICATION OF CELL PITCH TO THE BRIQUETTING OF ORE FINES, FLUE DUST, ETC.*

The properties of cell pitch described above (p. 75) can be made full use of in the briquetting of fine ores, flue dust, etc. For these purposes it offers special advantages over coal tar pitch. The ideas raised originally that the solubility in water of the binding material would bring about disintegration of the briquettes owing to the presence of moisture in the blast-furnace gases were proved to be groundless by a series of experimental observations. Further, the fears regarding the sulphur content of the cell pitch did not materialise. The cell-pitch ore or flue-dust briquettes do not disintegrate, and the slight sulphur content of the binding material does not exert any deleterious influences.

Dr Trainer's Cell-Pitch Method (Gewerkschaft Eduard)

In outline, the execution of the method is similar to that described above for the briquetting of coal and cokes. After adding the required amount of cell pitch, the briquetting material is thoroughly mixed in a mixer or steam kneader. It is then treated with superheated steam and compressed in specially strong toggle-joint presses under very high pressures (400–500 kgs. per sq. cm.).

The costs of installation of a two-press factory for fine ores or flue dust amount to about the same as for a coal installation, namely, about 295,000 M. inclusive of the costs of land and railway sidings (30,000 and 25,000 M.), or 240,000 M. exclusive of these items.

The simple costs of production of ore briquettes, which because of their higher density permit of a higher output per press by weight,

are about 55 pf. per ton less than for coal briquettes, amounting to therefore

With 4 per cent. pitch addition	. .	2·45 M.
„ 4½ „	. . .	2·65 „
„ 5 „	. .	2·85 „
„ 5½ „	. . „	3·05 „
„ 6 „	.	3·25 „
„ 6½ „	. .	3·45 „
„ 7 „	. .	3·65 „
„ 7½ „	. .	3·85 „
„ 8 „	. . .	4·05 „

A preliminary or subsequent treatment of the briquetting material or briquettes, with the object of obtaining water and weather resisting qualities, is necessary only in very few cases, and then the costs are increased by 1 to 1·50 M. per ton.

This cell pitch method has been applied on the large scale at the iron works of the Gewerkschaft Deutscher Kaiser in Bruckhausen, Ruhrort.

At this works the "Vereinigten Gewerkschaften Eduard und Pionier of Walsum a. R., the makers of cell pitch, erected a factory at their own costs, and worked it for several months in the year 1908. The experiments were so successful that in the summer of 1909 the Gewerkschaft Deutscher Kaiser took over the briquette factory and made with the above firm an agreement of several years' standing for the supply of cell pitch, permitting of the briquetting of 100 tons flue dust per day. At the present time 180 tons of flue dust briquettes are made per day, using an addition of 4½ per cent. cell pitch. From the press the briquettes are sent direct to the blast furnace. As already remarked, cell pitch briquettes neither disintegrate in the furnace, nor is any deleterious effect exerted by the sulphur in the bond. Further advantages are :—

1. Cell-pitch briquettes are completely reduced.

2. They exert a favourable influence on the ore situated in the same zone of the furnace.

3. If, for example, 15 per cent. briquettes replace an equal amount of ore in the charge, a diminution of about 30 per cent. takes place in the dust produced. In addition, a not inconsiderable increase in the yield of iron is obtained with a lower coke consumption.

4. Briquetting with Naphthalene, Paraffin, Molasses.

An older proposal of Fegan (D.R.P. 81,906), to apply naphthalene or paraffin,[1] has proved unsuitable because of the high value of the materials.

[1] Cf. Vol. I. of this Handbook, p. 43 and p. 110.

Dunkelberg's method in which a mixture of molasses and kieselguhr act as the bond has already been dealt with on p 65

5 and 6 Briquetting with Resin and Starch.

According to Edison's method (D R P 132097) resin soap[1] whose adhesive properties are well known is used as a binding agent It is, however too costly and in addition the bricks must be pressed hot and subjected to a subsequent coking

Similar remarks apply to the method of Marton Budapest in which starch[2] from maize and weeds is used The starch is liquefied under high pressure mixed with the fine ore, and the mixture compressed to egg briquettes

METHOD OF BRIQUETTING FOR METALLURGICAL PRODUCTS.

The Mansfeld process for flue dust containing lead[3] consists of a simple compression of the flue dust accumulated at the various copper schist smelting works of the Mansfeld Company After calcination the briquettes are supplied to the Eckhardt smelting operation and fused up in a rectangular furnace, with coke, iron rich slags, pig iron etc., to silver-bearing lead and nickel speiss

At the silver works of the Anhaltischen Blei und Silberwerke[4] at Sudharz the whole of the flue dust (containing about 50 per cent lead, some copper, and a few per cents of antimony) is mixed with burnt lime and purple ore from the pyrites roasted locally in such proportions that in the absence of zinc a readily fusible slag containing 28 per cent. SiO_2, 35 per cent. FeO, and 16 per cent CaO is obtained when the hand-moulded bricks are subsequently smelted. If zinc is present, the amount of lime is limited until the slag contains only 10 per cent. lime.

The Zinkoxydanlage Oker G m b. H[5] of Oker, Harz, works up the zinciferous slags obtained in the neighbouring Koniglichen und Herzoglichen Kommunion Huttenwerks. The slags are finely ground and briquetted in the usual way with coal-tar pitch in an egg-roll press. Three such briquettes are illustrated in fig. 6 (1, 1*a* and 1*b*)

[1] and [2] *Cf* Vol I of this Handbook, p 47

[3] See anniversary communication of the Mansfeld'schen Kupferschiefer bauenden Gewerkschaft to the *X. deutsch Bergmannstage*, p 160, 1907

[4] Private communication

[5] According to information supplied by the company

They each weigh 0.4 kg. The subsequent method of working to zinc oxide is still kept a secret.

Briquetting of Iron and Metal Swarf.

A. Rónay's method (D.R.P. 158,472) has already been dealt with in its application to ores, flue dust, etc., on p. 36 *et seq.*, and is suitable for and used at several places for briquetting all kinds of iron and other metal swarf.

The filings, turnings or drillings of wrought iron, cast iron, or steel accumulated in machine shops are first separated from non-magnetic metals by means of a small magnetic separator, which at the same time removes dust, pieces of wood and other foreign materials. It is then delivered to a suitable powerful hydraulic press either after moistening with water or before having been further treated in any way. Compression is effected gradually or step by step up to a very high final pressure (upwards of 1200–2000 atmospheres), whereby all the included air is driven out from between the particles of metal, and dense strong briquettes result.

Cast iron briquettes prepared from fresh swarf moistened with water heat up for some hours after compression, and when broken reveal a fractured surface which is dark brown in colour indicating that a certain very small amount of rust has been formed. Moistening the swarf is not essential, but in the dry state a higher end-pressure must be applied.

Various iron and steel briquettes are illustrated in fig. 3 (9, 10, 11, and 12).

The swarf from other metals and metallic alloys is treated in exactly the same manner, except that magnetic separation is only resorted to when the swarf is mixed with particles of iron.

Briquetting occasions a considerable increase in value of the swarf, and generally raises its price to above that of the scrap of the same metal.

The scrap price for wrought iron and steel is about 15 M., and that of cast iron 30–35 M. above the price of the corresponding swarf. This is due to the greater losses, particularly with fine swarf, taking place during melting in a Martin furnace or a cupola, and also to the considerable loss of iron as iron oxide in the slag. In loose swarf a total loss of at least 50 per cent. must usually be provided for. However, systematic research has proved that cast-iron swarf briquettes lose at the very outside 8–10 per cent. when melted alone, and only about 4 per cent. when fused with pig iron in the proportion of 80 : 20. When pig iron is melted alone the loss varies from 3 to 5 per cent.

Further experiments by A. Borsig, Berlin-Tegel, and tests made at other works have proved that swarf briquettes yield considerably better castings, particularly in point of view of greater density, toughness and strength, so that they can be substituted for the expensive brands of iron used in making high quality castings with considerable economical results.

The mode of action of the briquettes may be explained as follows. All materials added to an iron mixture to reduce the total carbon by virtue of their own low carbon contents do not appear in practice to have the desired results since they absorb carbon again during fusion. With cast iron briquettes, however, the reverse is the case. Compared with loose swarf, the compact form of the briquettes protects the material against strong oxidation in the upper part of the furnace and against slagging off. At the same time the structure, although briquettes can be obtained with a specific gravity of 6·8, is more open compared with the massive pig iron, so that the graphite present in the briquette is burnt off just above the fusion zone. The subsequent carbonising process occurring during the period of fusion cannot quite replace the carbon lost in this way, the net result, therefore, being a considerable reduction in the total carbon.

Metallurgical operations using steel scrap, such as small Bessemer plants, steel foundries and large open hearth plants, find in steel and wrought iron swarf briquettes a cheaper substitute and one which behaves better in the furnace. This has been shown by experiment at the Friedenshütte und Borsigwerk in Upper Silesia as evidenced by the following report:—

FRIEDENSHÜTTE, MORGENROTH O/S., *June* 1909.

Report on the melting tests made with steel swarf briquettes in the Martin steel works of the Friedenshütte. The briquettes were pressed from coarse drillings into cubes of 8–10 kgs. weight and used as a substitute for small scrap.

In Test No. 1, made on 9th June 1909, briquettes constituted 53 per cent. of the total charge of 20·5 tons, or 77 per cent. of the scrap added.

The charge was made up of:

$\left.\begin{array}{lll} 53 \text{ per cent.} & \text{briquettes} \\ 16 \quad ,, & \text{scrap} \end{array}\right\}$ 69 per cent. briquettes and scrap
31 ,, pig iron.

In Test No. 2, made on 29th June 1908, 17 per cent. of the total charge of 21 tons was made up of briquettes, equal to 26 per cent. of the usual amount of scrap added. The charge was thus made up of

$\left.\begin{array}{lll} 17 \text{ per cent.} & \text{briquettes} \\ 48 \quad ,, & \text{scrap} \end{array}\right\}$ 65 per cent. briquettes and scrap
35 ,, pig iron.

The charging period, reckoned from the beginning of charging to the melting, was 50 minutes in case No. 1 and 30 minutes in case No 2 shorter than in the case of the comparative charges melted in the same furnace with the same percentage of loose swarf

The melting period, so far as two experiments can be made comparative, was 25 minutes in case No. 1 and 15 minutes in case No. 2 shorter than that observed in the comparative heats. In this connection, it must be remarked that briquettes (10,900 kgs in case No 1, 3500 kgs in case No. 2) can all be charged at once, while loose swarf must be introduced in several stages Exact data with regard to these points, and the favourable melting losses obtained by the use of a material compressed to a density of 5, must only be given as reliable average values after a longer period of working

The saving in time, apart from other allied advantages, was equal to an increased output of about 2 3000 tons per furnace per annum according to the percentage amount of loose swarf, assuming that about 7½ charges of 20 22 tons were put through every 18 hours

The total amount of about 15 tons briquettes, melted in the tests described, occupied 12 boxes, while an equal quantity of loose swarf would occupy 33 boxes It was also shown that in the observed loading of 11 tons briquettes into 9 boxes 3 men and 33 minutes could be saved as compared with shovelling the same quantity of loose swarf into 24 boxes With heavier briquettes and their production is by no means impossible the advantages enumerated above must be considerably increased

License for the production of iron and metal swarf briquettes by the Rónay system (Allgemeine Brikettierungsgesellschaft, Berlin m. b. H.) has been taken up by the "Hochdruckbrikettierung" G. m. b. H. Berlin.[1]

Application on the Industrial Scale.—Various plants have already been commenced in and out of Germany for the working of this process, *e.g.* "Sachsische Metallbrikettwerke," Chemnitz, A Borsig, Berlin-Tegel, "Berliner Eisenbrikettwerke," "Wiener Brikettgesellschaft," "Leeds Metal Briquetting Works," and many others.

The *Method of L. Weiss*, Budapest (D.R P. 175,657) is intended for metal swarf as well as for ores and salts (see p 34) By this method the metal swarf is moistened with dilute magnesium and calcium sulphate solution and compressed under high pressures, while in another mode of operation, intended for iron swarf (D R P. 178,303), the swarf is moistened with lime water and moulded in a press.

In agreement with the patent specification the briquettes produced by this method, particularly those from pig- or cast-iron swarf, undergo

[1] See brochure issued by this firm, "Das Brikettieren von Eisen- und Metallspänen ohne Bindemittel (System Rónay)," 1909.

a certain amount of heating up for some time after their removal from the press. With irons poor in carbon such as wrought iron the effect is much less energetic so that the heating up is not noticed but binding action certainly takes place. In all cases there is no sign of a considerable formation of rust. The pressed blocks acquire a relatively high strength.

Briquettes produced from fresh cast iron swarf moistened with lime water show, after breaking, grey shimmering fractured surfaces without rust specks even after two months' storage. It appears, therefore, that the lime content effectively inhibits the formation of rust, a fact of considerable importance in preventing loss during smelting.

It is at least doubtful if the addition of lime water is of still greater importance in the production of briquettes, since swarf can be converted into briquettes of ample strength without such additions, if only the pressure is high enough. This and the other briquetting methods of L. Weiss are carried out by Nay & Strauss of Budapest, who some years ago built, and have since kept in operation a Central Briquetting Plant for iron and other metal swarf obtained from the various workshops of the town. The swarf briquettes of wrought iron (1) cast iron (2) bronze (3), white metal (4) and copper (5) illustrated in fig. 5, have been produced in this plant. They all possess an elegant appearance.

Binding with Additions. According to the patent specifications, the iron swarf can also be mixed with additions, the mixture moistened with lime water and compressed to briquettes.

If, for example, an addition of dolomite or chalk and some coke is applied, the method is carried out by first adding to the iron swarf 2 to 4 per cent finely ground dolomite or limestone. This serves to fix the sulphur and render the iron soft. To this mixture 1 to 2 per cent wood charcoal or graphite is added, and the whole is moistened with lime water in mixing drums, and compressed to briquettes under a high pressure in the usual way. The pressed blocks leave the press cold, but chemical reactions are set up during storage, and the temperature rises up to 50 or 60° C. This heating up, and the chemical reactions causing it, proceed for about 24 hours, during which time the briquettes become bound and completely resistant to the action of water. Under certain conditions the blocks can be sprayed with lime water during setting.

C. SUMMARY.

The conversion into bricks or agglomeration of ores, flue dust and similar materials without the use of binding materials, prevents the introduction of impurities into, and impoverishment of, the materials

Generally speaking, therefore, it has advantages over the method of briquetting with binding materials in cases where the costs are not too high and the pressed blocks or agglomerates conform to the requirements with regard to strength and behaviour in the furnace, dealt with in detail in Section I. As a result, briquetting without the use of binding materials can only be carried out successfully-

1. When the material to be briquetted contains enough of a suitable binding material (more especially clay) whose water of hydration can be driven off by burning the pressed blocks, or
2. When (as in the case of certain kinds of flue dust) the latent binding properties existing in the briquetting material can be brought into play by grinding, or by the addition of small quantities of exciting materials in the form of solution (this however, brings about a certain amount of impurification), and the pressed blocks strengthened by heating in superheated steam (Schumacher, Weiss), or
3. When by removing enclosed air as completely as possible, and by application of exceedingly high end-pressures the briquetting material can be compressed into blocks (Ronay), or
4. When the pressed blocks (of magnetic iron or purple ore) can be sintered by powerful ignition in a Grondal channel oven.

In the various methods of agglomeration, moulds and presses and their attendant costs, not chargeable to smelting, can be dispensed with. However, a successful result is only obtained when there is an ample gap between the sintering and fusion temperatures of the fine material, and the actual fusion of the material can be effectively prevented during the operation. Raduschewitz' method, agglomeration in the Petersson roasting furnace, the Scott shaft furnace, and the revolving tube furnace, can be readily applied to certain ores and mixtures, particularly if fuels can be obtained cheaply. Nevertheless, many of the fusion-agglomeration processes have failed because of the unsuitability of their products for the process of smelting.

Brick making, after the addition of binding materials, is always carried on where supplies of ores which can be used as bonds, such as clayey iron ores, washery products, powdery brown-iron ores, purple ores containing sodium sulphate after the leaching out of the copper and so on, are available. Due regard must here be paid to the fact that water of hydration must be subsequently removed by calcining the briquettes.

Application of other inorganic binding materials possesses the disadvantage of lowering the iron content of the material. This is particularly the case in the application of non-ferruginous clays, since in order to get sufficient binding after calcination, it is necessary to add such a large quantity.

Binding with lime, in the shape of natural or artificially prepared calcium carbonate or burnt or slaked lime results in early disintegration of the briquettes in the blast furnace as a result of the unavoidable chemical changes which take place. On the other hand those methods depending upon the formation of lime silicate or silicates of lime and alumina which are not decomposed on heating (Schumacher's quartz meal lime method and the Scoria method) can be adopted in many cases particularly where the necessary materials are cheap and only small quantities are required, where the costs of working are low and where the silicate can readily be sintered at a red heat.

Further methods depending upon the use of plaster of Paris, cement, various forms of blast furnace and open hearth slag, water glass and similar materials have not proved suitable either because the resulting briquettes disintegrate in the furnace or because of the high prices of the binding materials.

Dunkelberg's method working partly with inorganic and partly with organic materials (carnallite, kieselguhr and molasses) together with subsequent calcination of the briquettes in a ring furnace, has apparently given good results in the case of iron-rich aniline residues and lixiviated burnt pyrites. It has not however been tested on a working scale for other materials, more especially flue dust.

In binding with organic materials (leaving the small quantity of ash out of consideration), the diminution of the iron content of the charge is prevented, and attempts have been made to utilise their combustion, together with that of the admixed small coal or coke, in the reduction carried on in the furnace, so that the high cost of the usually expensive organic materials is partly compensated for by a saving in the lump coke utilised. The intimate contact of the finely divided binding material with the individual grains of ore always gives rise to a direct reduction (by carbon), while the furnaceman always strives after the much more advantageous indirect reduction by means of carbon monoxide.

Of the other various proposals which have been made, consideration must be given to that of Huffelmann (coke or charcoal stubble with pitch), which appears to possess certain advantages. Still more

consideration must be given to Trainer's cell pitch method on account of the exceedingly favourable properties of this new binding material, now made on the large scale from wood pulp, waste liquors, always available in large quantities. The process is well adapted to, and is finding continually increasing application in, the manufacture of fuel briquettes, particularly from coke and anthracite.

The methods described above for the briquetting of metallurgical products (flue dust from lead furnaces, zinc slags, etc.) were at first applied in few places, but are now applied at various works with satisfactory results. Similar remarks apply to the methods of Ronay and Weiss for the briquetting of swarf from iron, steel and other metals

SECTION IV.

PREPARATION OF THE BRIQUETTING MATERIAL.

In relatively few cases can the ore metallurgical product etc. be supplied to the briquette press for moulding and compression without being subjected to some preliminary form of treatment. The bulk of raw products require a more or less comprehensive dressing, depending upon the nature, composition, size of particles properties, moisture content etc., of the material, and the possible binding or catalytic agent, and also upon the details of the method to be applied. The operations of preparation may include a complete or partial dressing (in the narrow sense of the term) consisting of opening out by coarse and fine crushing followed by concentration, simple crushing to coarse particles, sieving off the fines, separation of or purification of iron swarf, moistening dry materials or drying wet ones, treatment with superheated steam, mixing various ores or similar materials together or with possible binding or catalytic agents, and other operations of a similar character.

In the following pages, operations and machines which really come within the scope of dressing will only be dealt with briefly but the remaining operations and appliances used in preparation will be dealt with in detail.

A. DRESSING.

I. Pulverising.

Coarse crushing of large, hard, and strong lumps is best effected by means of a stone breaker (jaw crusher) of the same or similar construction to those described in Vol. I of this Handbook (p. 59 *et seq.*, fig. 14), or by means of a revolving breaker, which is built on the principle of a coffee-mill, and possesses the advantage of working continuously, with a resulting greater output.

Fig. 8 shows the transport of poor magnetic iron ores coarsely broken by means of a stone breaker, to the storage bins for crude ores waiting for further crushing and magnetic concentration.

Fine crushing of material in hard, small lumps is best effected by means of ball mills with steel balls, which, during the revolution of the drum, crush the material step by step. Stamp batteries with alternately lifting and falling stamps are also suitable. Extremely fine grinding of granular, but somewhat softer, material is best effected in long cylin-

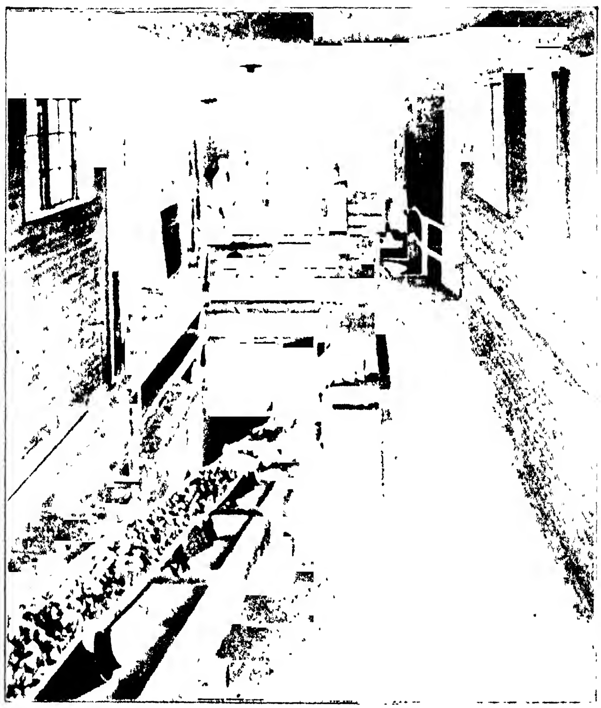


FIG. 8. Band conveyor with broken magnetic iron ore at a Swedish dressing and briquette works using the Gröndal system.

drical tube mills (Griess mills), in which it is crushed and ground to the finest meal or powder by the slow revolution of a number of rolling flints. For small-grained material of medium hardness, such as, for example, blast-furnace slags, edge runners (Vol. I p. 68 *et seq.*, figs. 19 and 20) can render excellent service, more especially when admixture has to be made with another material which is soft or of medium hardness and requires simultaneous grinding.

All kinds of pulverising machinery, particularly for ores and other

hard materials can be obtained in superior design and construction from all firms of repute engaged in the manufacture of ore dressing machinery, such as the Maschinenbauanstalt Humboldt of Cologne Fried Krupp Akt Ges Grusonwerke of Magdeburg Buckau etc in Germany

II. Sieving.

Separation of the fine ores for briquetting from the coarse ores for direct smelting is effected by impact or shaking sieves sieves swung by means of an eccentric, or by revolving conical or inclined cylindrical drum sieves

III. Concentration.

Poor finely powdered ores can be concentrated, either by the wet mechanical method adopted for most kind of minerals in which advantage is taken of differences in specific gravity influencing the rate of settling in water or by magnetic dressing of damp or dry material in which advantage is taken of the magnetic properties of pure iron ores

As a result of greater completeness smaller losses, and often lower costs magnetic concentration (particularly for strongly magnetic materials like magnetite and roasted spathic iron ore) is rightly preferred to the wet mechanical methods using hydraulic separators

Strongly magnetic iron ores are freed from foreign gangue and other ores by means of magnetic separators with moderately strong field-magnets capable of working wet or dry Dry separators are used especially for roasted impure spathic iron ores whose ore constituents have been converted into magnetic iron oxide (Fe_3O_4), while wet separators serve to work up very finely divided magnetites and roasted spars carried away with the wash waters in the form of slimes during the dressing of ironstones in hydraulic separators.

Weak magnetic iron ores are separated dry in special separators provided with very strong field-magnets. The "spathicised blende" (a mixture of crude spathic iron ore and the equally specifically heavy zinc-blende) obtained as an intermediate product in the hydraulic separator can be treated with advantage in this way

The large firms mentioned above in connection with dressing plant also deliver excellently constructed magnetic ore separators suitable for the various purposes.[1] There is only space here for the illustration of

[1] Further information with regard to magnetic separators is given in the printed illustrated pamphlets of the firms

a Swedish wet magnetic separating plant dealing with finely ground poor magnetic iron ores (fig. 9). This consists of a number of revolving drum separators, Grondal Type 3, arranged one behind the other in pairs. Fig. 10 represents the Grondal shaking plant for the collection

FIG. 9. Magnetic separating plant at a Swedish briquetting plant using the Grondal system.

and dehydration of the pure magnetic iron ore concentrates which flow along with the excess of water into the chests shaken vigorously by mechanical means. The water is thrown out of the top, the ore compressed, finally tipped out, and supplied to the briquette presses.

A more intimate description of the magnetic separator systems employed in Sweden is given in the later sections on Complete Briquetting and Agglomeration Plants.

IV. Separation and Purification of Iron Swarf.

Special magnetic separators for separating metallic iron,[1] usually of the drum type, are used for iron granules, roll cinder, converter waste, filings, drillings, turnings, swarf from moulding sand, scrap from blast-furnace works, foundries, steel works, rolling mills, slag

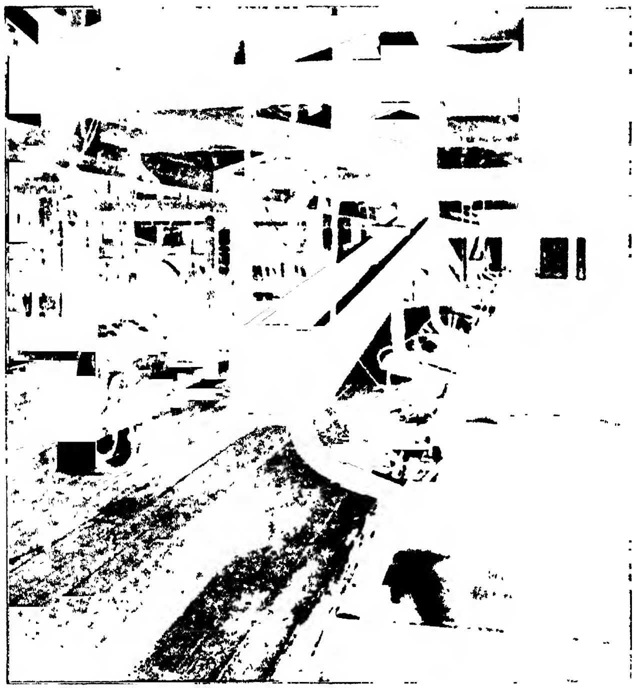


Fig. 10.—Gröndal shaking-chest plant. Dehydration of the magnetic iron ore concentrates obtained electro-magnetically.

mills, machine shops, and so on. They are provided with weak magnetic fields like the separators used for strongly magnetic ores, and may be either fixed or portable.

B. DRYING OR MOISTENING.

Slimy ores, ore concentrates, lixiviated burnt pyrites, and similar materials often contain too much water for immediate pressing and

[1] See the corresponding pamphlets of the Maschinenbauanstalt Humboldt, Fried. Krupp Akt. Ges. Grusonwerke, Siemens-Schuckertwerke, and others.

the excess must be first removed by drying. Similar remarks apply to many binding materials. On the other hand, many ores, flue dusts, and iron and metal swarfs may, under certain circumstances, be too dry and require moistening.

For each particular case the correct moisture content for the briquetting material must be determined by experiment. Certain materials and methods require 4 per cent. moisture, others require more or less according to circumstances.

I. Drying.

Complete information on the calculation of the amount of water to be removed, the general conditions of drying, and the available sources of heat is given on pp. 100–101 and p. 347 *et seq.* of Vol. I. Since the materials to be dealt with in this connection are non-combustible, artificial drying is generally carried on with gases from a fire, or by means of blast furnace gases mixed with air.

The drying arrangements preferred in connection with ore briquetting or agglomeration plants are movable drum dryers and fixed drying ovens, more particularly of the channel type.

Petry & Hecking's Flame-heated Drying Drum

The construction and operation of this drying drum has already been described in Vol. I. of this Handbook (p. 85), and illustrated by figs. 32–34, since it is applied at many places for the drying of wet coals. A dryer of this type 9·5 metres in length and 1·75 metres in diameter has been in use at the Ilseder Hutte since about 1905 for drying clayey ores in summer and washery sand from the local iron-ore washing plant in winter.

Argillaceous ores generally freeze to lumps in winter, and are then most advantageously added to the hot washed sand in the mixing machine. The washed sand, however, is always delivered to the briquetting plant at a uniform temperature and with a constant moisture content.

Angle irons fixed parallel to the longitudinal axis of the horizontal iron drum carry the material round during revolution and then allow it to fall again. By this means the material is thoroughly mixed and brought into intimate contact with the hot gases. Shovels placed between and inclined to the angle irons serve for carrying the material towards the discharging end of the drum. By altering their number or angle of inclination it becomes possible to regulate the rate of flow through the dryer. The drum is fitted with two running tracks, each

of which runs on two wheels. Drive is effected by means of a three-phase motor through a belt transmission to bevel wheels and a pinion engaging with a spur wheel on the drum. The speed is about 10 revolutions per minute.

Heating with Blast-Furnace Gas (fig. 11).—Purified blast-furnace gases are used for heating the drum. The Ilseder Hütte has installed their own system of heating which has been found to give good results in the firing of boilers by means of blast-furnace gas. The gas issues from the main through a cast-iron box into the fire

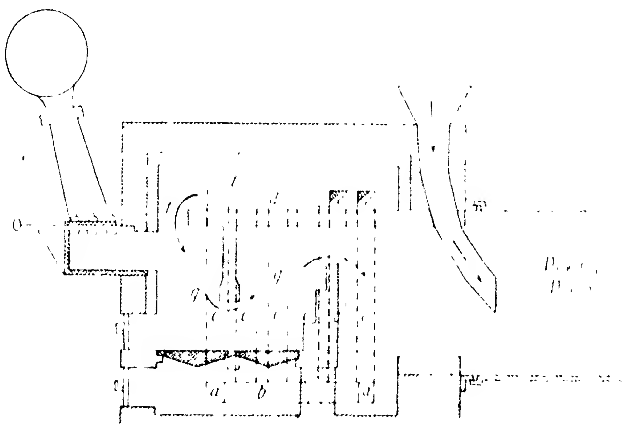


FIG. 11.—Blast-furnace gas firing on a Petry & Hecking fire-heated drying drum.

space and the supply can be regulated by a sliding valve. Air for combustion enters through adjustable openings a in the walls of the furnace into the horizontal channel b, from which it rises up the vertical channels c in the oven walls. In this way the air becomes pre-heated and the walls cooled. Then the air enters the combustion chamber through the two openings e and mixes with the gas near the inlet f. Combustion takes place in the fire-box g, and the flames and hot gases stream into the drying drum across the fire bridge.

Auxiliary Firing.—Since the gas supply from the blast furnaces is subject to considerable fluctuations often being completely cut off during lowering of the bell, a small fire of waste coke is kept burning steadily on the grate in order to ignite the gas after an interruption and thus prevent an explosion. The stream of gas is deflected by a cross wall in the fire-box so as to pass close over the coke fire.

Originally a fan was placed at the back of the drum to create the necessary draught, but it soon became stopped up by the fine ore and clay dusts produced in the drum and had to be put out of action The drying plant has, therefore, been connected to the 70-metre chimney of the Cowper stoves attached to No. 2 blast furnace.

Dust Removal. -At first great difficulty was experienced in dealing with the large quantities of dust formed during the drying of ores A large dust chamber, somewhat egg shaped in section, was first arranged above the drum, the accumulated dust being removed by means of a worm conveyor at its base. The dust, however, lay so thick on the floor that the worm could not be kept revolving Similarly, horizontal pipes became choked up in a very short space of time

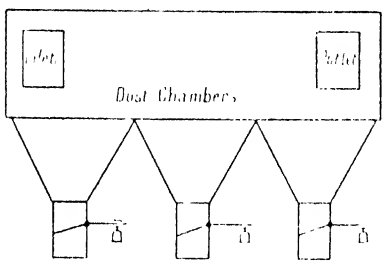


Fig. 12. Dust chambers for catching and removing flue dust.

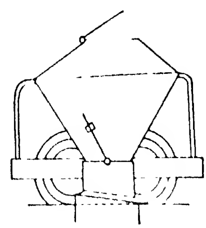


Fig. 13. Dust-tight carriage for the removal of flue dust.

Subsequently the Ilseder Hutte built three dust chambers 5 metres long and 1 metre wide (fig. 12), from which the dust could readily be removed in waggons. At the same time the pipes, like the blast-furnace main, were directed upwards and downwards at sharp acute angles, so that the dust must be deposited in the dust chambers. The drying plant is thoroughly cleaned out once every month

In order to protect the workers from dust the drying drums discharge into dust-tight waggons (fig. 13), which convey the material to the upper storey of the briquette factory. The waggons are provided below with an iron box cut off at an angle corresponding to a piece cast on to the loading hopper, and with which it engages and ensures that no dust is produced when the waggon is emptied on opening the base by turning a small lever at the side. The waggon can be closed at the top by means of a cover provided.

Moller & Pfeifer's Drying Drum System (figs. 14–15)

The Moller & Pfeifer type of drying drum[1] consists of a long inclined wrought iron drum divided internally into cells through which the material to be dried has an interrupted passage and becomes thoroughly divided up during the rotation of the drum. At the same time a strong current of air and gas is led through in the same direction as represented diagrammatically in fig. 14. (The cells are omitted from the diagram.)

Production and Introduction of the Hot Gases.—In the preparation of the raw material for the cement industry as well as for ore briquetting the supply of heat is obtained almost exclusively from a special fireplace, but in some cases waste gases are employed if they

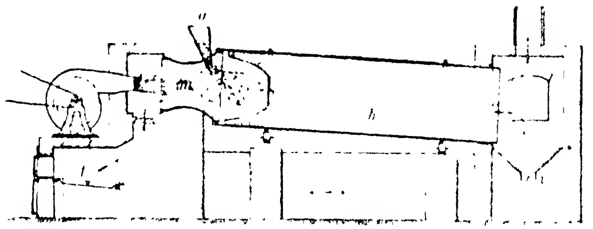


Fig. 14.—Diagram [illegible]

are available at a sufficiently high temperature. Since the temperature generated on complete combustion of fuel is too high to permit of the gases being brought into immediate contact with iron construction without fear of damage, the fresh fire gases are mixed with gases previously exposed to the material to be dried. In this way a better utilisation of the heat and higher evaporative figures are obtained. For this purpose the mixing nozzle (ejector) *m* is operated by a stream of compressed air *l* from the fan *s*. Fire gases are drawn from the grate *f* along with used gas from the return channel; the two are mixed with the compressed air and the mixture is blown into the drum *h* against the stream of fresh moist material falling from the supply hopper *a*. By means of this arrangement it is possible to fix the temperature of the gases at any desired figure by varying the

[1] Möller & Pfeifer, pamphlet on Design and Arrangement of Drying Plant, Channel Combustion Stoves, Roasting and Calcining Apparatus by their own patented processes. Berlin W. 10, Friedrich-Wilhelmstrasse 19.

proportion and to allow to pass through the grate only that quantity of air necessary for complete combustion.

In order to observe the temperature of the current of gases a suitable thermometer is employed. Its lower end is pushed through an inclined hole in the back wall of the delivery chamber, and during correct working indicates a temperature of 120° C.

Arrangement and Design of the Cells. The material to be dried falls through a hopper into the conical drum head from whence it is fed uniformly into the individual cells by means of spiral shovels and other appliances. The cells may be of various shapes, dimensions, and sizes according to the particular characteristics of the material to be treated, but the most general arrangement and design is as follows. In the first short section of the drum the cells are formed by six sheet iron divisions arranged radially round the axis of the drum while in the next section these cells are further divided by a number of con-

Fig. 15.—Arrangement of the cells in a Möller & Pfeifer drying drum. Cross and longitudinal sections.

centric circles into smaller divisions which are further subdivided into still smaller cells by radial sheet iron strips (fig. 15).

In this way the material is distributed uniformly over the whole section of the drum during its revolution, and a large surface is exposed to the action of the stream of gases. Further, even when the drum contains a large charge the height of the layers in the individual cells over the whole length of the drum can only be very small. Those moist surfaces of the particles not subject to the direct action of the gases lie on the heated iron plates where they become heated up and promote drying. When dry the material rolls out at the lower end of the drum into a hopper and is conveyed to its destination by any recognised conveyor system.

Dust Formation and Separation. In consequence of the short drop in the small cells the formation of dust is relatively small. Large drying plants for materials readily falling to powder such as limestone, blast furnace slags, etc. have the return channel arranged as a large dust chamber provided with dust catchers and

worm conveyers to continually remove the collected dust. Provision must be made by suitably regulating the fan to prevent too much fine dust being carried forward with the returning stream of gases in the return channel.

Removal of the Exhaust. The stream of gases carries with it the moisture evolved from the material to be dried, but must obviously not be allowed to become super-saturated during the cycle of operations described. Consequently a portion of the gases which have passed through the drum must be led away to the chimney and replaced by a fresh supply of air from the fan. In fig. 14 the path of the exhaust into the flue is indicated by an arrow in the top of the discharge chamber. A more effective design of drier, however, has the flue in the top of the fore chamber containing the fan. The whole installation is arranged in such a way that when the fan, etc., is correctly adjusted the chimney does not exert an actual pulling effect, but simply leads away the quantity of exhaust controlled by a flap valve.

Heat-Insulating Cover, Mounting and Drive. The drum is surrounded by an air space[1] enclosed by an iron jacket for the purpose of heat insulation. It runs freely on strong slightly conical rollers whose horizontal bearings are easily accessible and are not heated up by the action of the hot gases. Drive is not effected by worm or toothed wheels but by friction between the rollers and the strong running tracks coned to correspond with the rollers. Since the drum is almost symmetrically loaded by the uniformly distributed material, the work expended in rotating the drum is very slight (5–9 H.P. according to the size).

Space Required. The drums are made in four sizes of 12·4 to 15·5 metres long, 4·5 to 6·2 metres wide, and 4·1 to 4·5 metres in height. The brickwork amounts to about 70 to 100 cubic metres.

The fireplace can be designed for all kinds of fuels. By means of the experimental station maintained by Möller & Pfeifer at their Heegermühle brick works in Eberswalde Mark, it is possible to test the requisite appliances for a new kind of material to be dried on a large practical scale before completion of the actual plant. Eight to ten types of drum driers, of which about four are suitable for ore briquetting, are made by this firm. The cost of these four types varies between 12,000 to 22,000 M., exclusive of conveying

[1] Extended experiments with various insulating materials have proved that air is by far the best.

appliances and buildings which are not provided by this firm except under very exceptional circumstances.

Distribution and Application of the Moller & Pfeifer Drum Dryer[1] Dryers of this approved system have been supplied to several hundred installations in Europe and oversea countries. For a long time they have found application in the cement and allied industries, and of late years have also been applied frequently in manure works, chemical works, salt and other mines, metallurgical works, and so on.

They serve for the drying of limestone, chalk, marl, clay, loam, concentrates, sand, blast furnace slag, wet cement slimes, bauxite, aluminium hydrate, phosphates, superphosphates, phosphate of lime, bone waste, basic slag, whale flesh, blood, waste horn, debris, fir cones, carbonate of magnesia, lime sludge, potassium chloride, common salt, pit coal, settled coal slimes, coke, anthracite briquettes, brown coals, copper ores, zinc blende (Hohenlohe Hütte, O.S.), lixiviated burnt pyrites or purple ores (Ver. Königs u. Laurahütte A.G., O.S.), and so on.

The latest application is at the Königshütte for the objects of briquetting. Here a cell drying drum dries 5000 kgs of moist burnt pyrites daily, of which more will be said in the description of the Königshütte briquetting plant, which will be given later.

Example of a Moller & Pfeifer Drying Plant with Preliminary Crushing (figs. 16 and 17). The arrangement serves for drying 15,000 kgs limestone containing 9–15 per cent water hourly, and the illustrations are self-explanatory. The raw material, which is partly in large lumps, is delivered by an overhead way to the upper platform and discharged into a large bin arranged above heavy double roll crushers. These crush the material to the size of nuts and then allow it to fall into the supply hoppers of two drum dryers. At the outfall end of the drum is situated an ascending collecting worm, which conveys the dried material into an elevator pit, whence it is lifted to the top storey of the rough mill. The exhaust is led through channels to the tall chimneys in the right gable end of the building. Power for the whole crushing and drying plant is obtained from a common main shaft on the inside of the wall in which the chimneys are built.

OTHER DRYING APPLIANCES

Of the remaining appliances which can be considered as useful for the drying of crude materials used in the manufacture of metal-

[1] From the firm's catalogue of drum drying plants.

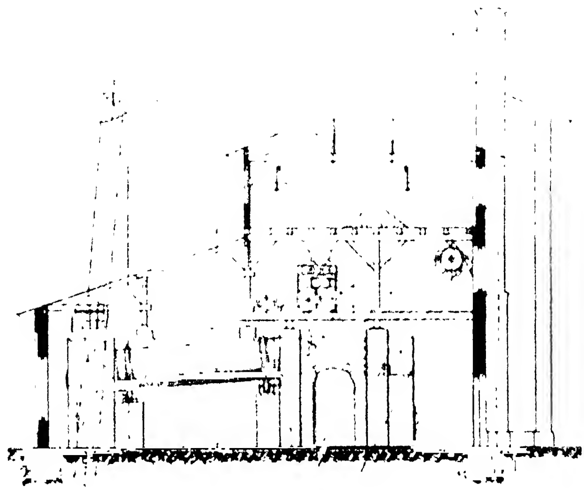


Fig. 16.—Möller & Pfeifer drying plant with preliminary crushers. Longitudinal Section.

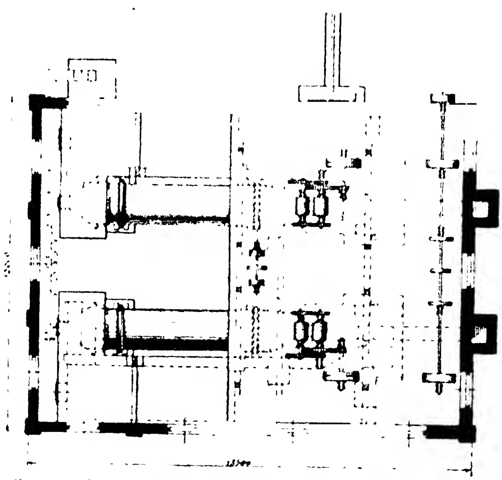


Fig. 17.—Möller & Pfeifer drying plant with preliminary crushers. Plan.

lurgical briquettes or agglomerates, the following may be considered here:—

Zeitzer Eisengiesserei Patent Drying Drum.—This apparatus, primarily intended for the drying of pit coal, is described in detail (p. 91 *et seq.*) and illustrated (figs. 35 and 36) in Vol. I. of this book.

Fellner & Ziegler's Drying Drum (Frankfurt a. M.).—This dryer has been widely used in the cement and allied industries for several years, and is also used for drying pit coal for the agglomeration plants built by this firm.

The **Shaft Dryer of Thomas A. Edison** (New Jersey, U.S.A.; D.R.P. 103,364) is intended specially for pulverised small ores lifted by a conveyor to the upper opening of the drying shaft and allowed to trickle down inclined distributing plates, which divide the material into a number of fine streams. The drying shaft is situated close to the fire-grate of a boiler. Air, heated by blowing through a system of pipes in the grate, is mixed with the fire gases, and introduced into the drying shaft and through pipes by means of an exhauster. Here it moves in the opposite direction to the material to be dried, which is ultimately caught in a hopper at the bottom.

The **Shaft Dryer of G. Grondal, Stockholm,** is very similar to the above in many ways. Its application at the Kerl Ironworks has already been mentioned on p. 33.

The various types of channel drying plants are less suitable for the drying of raw material than for briquettes, and are therefore described in Section V.

II. Moistening.

The mixing of argillaceous ores with water, dealt with on p. 32, is effected by hand in exactly the same way as ordinary bricks are made; otherwise it is very seldom necessary to moisten the raw material with water, and when necessity arises the operation is carried out either with a watering-can or a spray attached to a water-pipe. The raw material can be moistened with other materials in exactly the same way.

If a thorough admixture with the liquid is required, the requisite quantity is added to the material to be sprinkled in a suitable mixing appliance. Further information on this point is given below under D.

C. TREATMENT WITH STEAM UNDER PRESSURE.

In the briquetting process of the Scoria Gesellschaft Dortmund (pp. 63, 64), a preliminary treatment with high-pressure steam is undertaken with the object of opening up the granulated blast furnace slag and converting it into a cement like powder possessing binding action. For this purpose the so-called slaking drum of the shape and arrangement shown in the illustrations of a Scoria briquette factory is reproduced in the section on Complete Briquette Plants.

Section V deals with the treatment of pressed blocks with high pressure steam for the process of hardening, an operation much more frequently carried out.

D. MIXING THE BRIQUETTING MATERIAL.

The appliances in general use in the briquetting of pit coals for the mixing of coal smalls with solid finely powered pitch or hot liquid soft pitch, etc., are also used for the intimate mixing of the various fine ores with one another or with one or several binding materials or catalytic agents.

This applies above all to mixing worms, into which the various materials are introduced from storage hoppers by means of rotating distributing tables and scrapers. The spiral or wings of the worm then thoroughly mix the material and at the same time convey it to the discharge opening. Such appliances are illustrated in figs. 15, 21, 22, 25, 27, and 158-164 of Vol. I.

Under certain conditions the mixing appliances for liquid soft pitch and the steam kneaders or stirrers, described and illustrated on pp. 78-79 and p. 102, can also be applied. A machine of different construction is the

Mixing or Preparation Machine of Brück, Kretschel & Co.

This machine (fig. 18), made by Brück, Kretschel & Co., Osnabruck, for the briquetting of ores and the like by Dr Schumacher's older method,[1] is exactly similar in principle but much more strongly built than their so-called preparation machine, introduced earlier for the production of lime-sandstones.

The briquetting material to be mixed is generally lifted to the top storey of the factory by means of an elevator, whence it falls into a charging hopper arranged immediately above the mixing machine,

[1] See p. 58 *et seq.* above.

which is somewhat pear-shaped in section. The casing consists of a cast-iron cover and two end-plates. Up to just above the half-way line the cover is double, forming a hollow space surrounding the bottom and the lower half of the side walls of the mixing chamber. This space is steam heated to prevent cooling of the briquetting material during mixing. The steam space has a capacity of 284 litres, and at the Ilseder Hutte is filled with live steam at 3½ atms. (above 137° C.), while at the Königshütte the pressure is above 6 atms., or 164° C. The steam is allowed to condense in the jacket, and the condensed

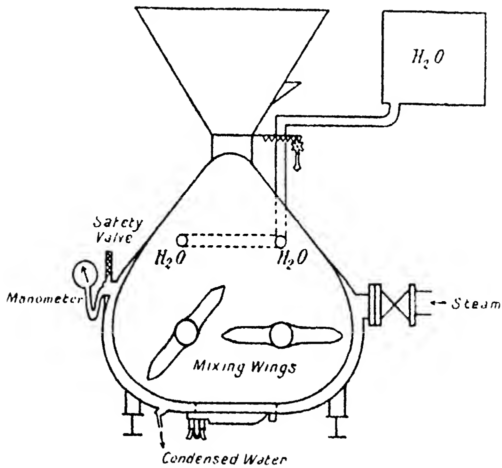


FIG. 18.—Bruck, Kretschel & Co.'s mixing machine. Cross section.

water outflow regulated by means of a steam-trap. A manometer and a safety-valve are connected to the steam space, which is also covered with felt to prevent loss by radiation.

The mixing space has a capacity of 5600 litres. Each end plate carries two stuffing-boxes, through which are carried the shafts of the mixing wings. Their bearings are situated outside the mixing chamber; thrust bearings are fixed to the driving side in order to take up the pressure of material on the wings. Each shaft carries two mixing wings in the form of a single steel casting, and by this means a thorough agitation and kneading of the material is effected. The shafts are driven at a speed of 4 revolutions per minute by means of a three-phase motor with belt transmission to a countershaft fitted with gear-wheels.

As a result of the steady friction between the briquetting material and the walls of the mixing chamber, the wear and tear is naturally very great. The side walls are most affected, and in order to hinder this wear they are covered with an iron plate 1 cm thick, which has to be renewed (at the Ilseder Hutte, for example) after four or five months.

Water Supply.—In some cases the briquetting material has to be brought up to its proper moisture content in the mixing machine.

At the Ilseder Hutte[1] steam is blown into the mixing machine at the commencement of operations. In this way, in addition to the introduction of moisture, the material was warmed up in a very convenient manner, but the regulation of the moisture content was difficult. This led to the introduction of water from an elevated tank through two perforated pipes situated parallel to the longitudinal axis of the machine, an arrangement which distributes water uniformly over the material, and has proved quite successful. From time to time the attendant takes samples, and determines the correctness of the moisture content by the feel of the material. This should be sufficiently plastic to permit of easy balling up in the hands.

Mixing is carried out continuously, and in order to attain a uniform product so far as is possible, a sufficient quantity of material is always kept in the hopper for one charge. This is drawn off into the mixing chamber, where it can be thoroughly worked up and mixed with the necessary quantity of water in 15 to 30 minutes. In the bottom is a discharge-opening closed by means of a strong cast-iron cover. When mixed the material is removed and conveyed to the charging hoppers of the briquette presses.

Mixing machines of this type are applied to the briquetting of ores and similar products at the Ilseder Hutte, the Königshutte in Upper Silesia, and other places, and are required to mix—

(1) At the Ilseder Hutte: 2 waggons argillaceous ores, 1 waggon washed sand, 1 waggon roll cinder, basic slag waste, and occasionally anthracite smalls.

(2) At the Königshutte: dried purple ore, wet purple ore, quicklime, and ground sand, with occasional flue dust rich in iron and Swedish ore concentrates.

In the preparation of lime sandstones, unslaked lime (quicklime) is mixed with sand in the mixing machine, when the lime obtains the

[1] According to a test made by Fulda.

water necessary for its hydration from the sand.[1] Simultaneously, chemical action takes place under the influence of the heat derived partly from the slaking and partly from the heat of the jacket, and the material becomes much more plastic and compressible. The sand, however, always has too low a moisture content (by 5 per cent. at the outside) to completely slake the lime, and the necessary additional amount of water must be added by the workman in the above or some other similar way.

In order to obtain a uniform mixing ratio of lime and sand the whole quantity of one charge must be added and removed from the mixer at one time.

[1] Slaking consists in the absorption of 32 parts water by 100 parts lime (CaO) to form calcium hydrate ($Ca(OH)_2$), with the development of a considerable quantity of heat

SECTION V.

COMPRESSION AND SUBSEQUENT TREATMENT OF BRIQUETTES FOR SMELTING AND FUSION.

A. PRESSING THE BRIQUETTING MATERIAL

It has already been laid down in Section III that apart from simple hand moulding, the briquetting material is subjected to low, medium, or high pressures, according to its composition properties and the requirements of the method chosen. In some cases it is necessary to finish off at a very high pressure.

I. Compression with Low or Medium Pressures.

By this method it is only possible to produce rough bricks adhering together so slightly that they can be broken in the hand. They only attain their full strength by burning at a very high temperature.

With very moist argillaceous ores, the Hertel rope press with cutting appliances, similar to that described on p. 606 *et seq.* of Vol. I. for the production of brown coal, wet-pressed blocks, and loam bricks, can be applied with advantage. For less plastic materials, however, drop-stamp presses and other brick-making presses are much more suitable and more frequently employed.

One of the most widely used drop stamp presses is the

Dorsten Drop Press (Brick Press), figs. 19 and 20.

The upper axle resting in three bearings on the uprights of the press body carries three cams which raise and allow the drop stamp, weighing about 400 kgs., to fall three times for each revolution. The cams are not of equal size, so that the three lifts are different. First, the loose material from the charging shaft is pressed into the mould below by a light blow. Immediately afterwards the charging slide returns, and the stamp falls upon the material twice from a height

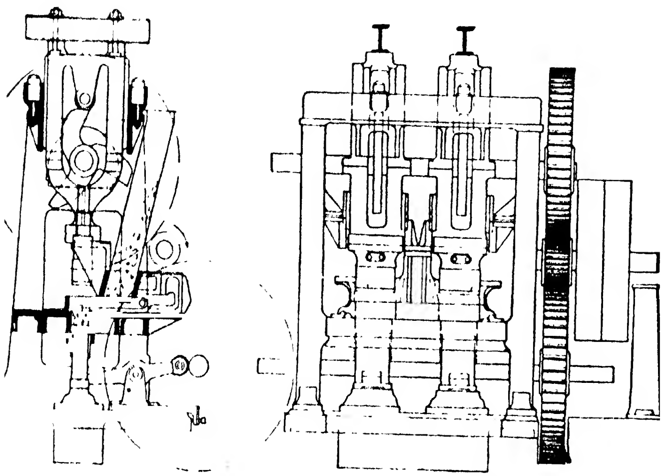


FIG. 19.—Dorsten Brick Press for two stamps. Cross section and front elevation (From vol ix. of the Niederrhein-Westfal *Sammelwerk*.)

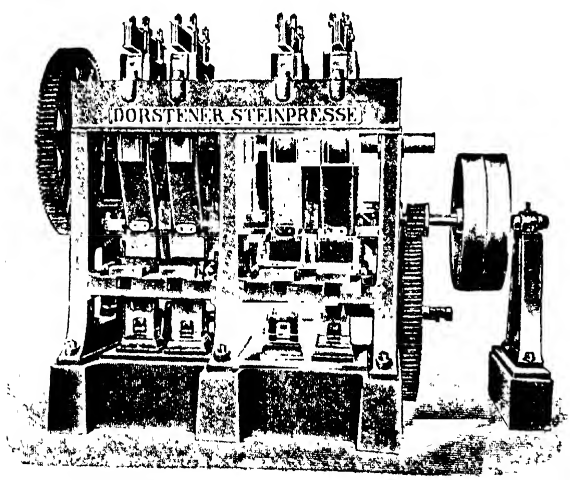


FIG. 20.—Dorsten Brick Press with four stamps.

of about 100 mm. and effects compression. After the third blow an elevator situated in the lower part of the press lifts the brick out of the mould to the level of the table, and the movement of the slide, filled with fresh material, pushes the brick forward ready for removal, which is effected after the first blow.

To facilitate the removal of the bricks the stamps and moulds are

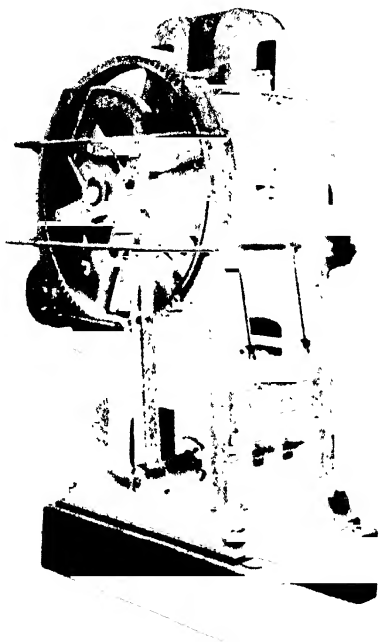


Fig. 21.—Single Stamp Drop Press. Grondal system

heated by means of steam. The moulds are lined with renewable steel plates perforated with fine holes to facilitate the escape of air from the pressed material.

At 36 to 39 revolutions of the shaft per minute the output of a press amounts to about 2100 to 2300 bricks per hour, while the power consumption is given as 3-4 H.P. Disadvantage is occasioned by the rapid wear of the mould walls, resulting in the edges of the brick not being strongly pressed. This gives rise to crumbling in the subsequent handling and use of the bricks.

Application to Ore Briquetting.—Drop presses of the Dorsten or similar types, such as the Gröndal (fig. 21), are used, more especially in Sweden, for compressing moist magnetic concentrates or purple ores prior to subsequent sintering in Gröndal channel furnaces.

For further information consult the section on "Complete Briquetting Plants." The experience gained with drop presses and Sutcliffe presses at the Helsingborg briquette works is communicated below in the description of the latter type of press.

II. Compression with Medium or High Pressures.

The general object is the conversion of the material into briquettes of sufficient strength for smelting or other treatment. For this purpose a medium pressure of a few hundred atmospheres to a high pressure of about 700 atmospheres is required, according to the natures of the material and of the bond

For a certain briquetting material and method it is most important to fix the most favourable compression pressure, that is, to fix a relation between the pressure applied in the mould and the degree of compression of the briquette obtained.

In this direction typical experiments have been carried out by the Ilseder Hutte with the testing press described on p 14 *et seq* and illustrated in fig 1. The magnitude of the pressure applied was read off on a manometer; the pressed blocks were cylindrical, so that their volumes could be compared simply by measuring their heights with a caliper square. The clay content of the ores served as binding material.

The results of the experiments are summarised in the compression curves shown in fig. 22, from which it appears that the best pressure is 300 atmospheres, since high pressures only slightly increase the volume weights of the briquettes. Consequently the briquette presses are built to work at this pressure.

The variation in the position of the two curves with regard to volume is occasioned by the fact that the two mixtures contained different amounts of moisture. A well-moistened material possesses a low volume weight on account of its content of water, it falls looser into the mould, and permits of a more powerful compression than a dry material, which lies densely in the mould after filling.

The whole of the briquette presses considered in this connection are pressure operated, and generally speaking, the remarks made with regard to coal-briquette presses (Vol. I. p. 112 *et seq.*) apply equally well here.

In addition to the briquetting of pit coals they are partially applied to the production of argillaceous shale bricks, slag blocks, lime sandstones, and other artificial stones, and, with the exception of egg-roll presses and the horizontal presses described below, they are all vertical presses, with single or double acting compression, and with or without revolving tables. Toggle-joint presses are also used.

Horizontal Press by Brück, Kretschel & Co. (figs. 23-27). This horizontal press, built by Bruck, Kretschel & Co of Osnabruck, was introduced into the brick-making industry in 1871 by F. W.

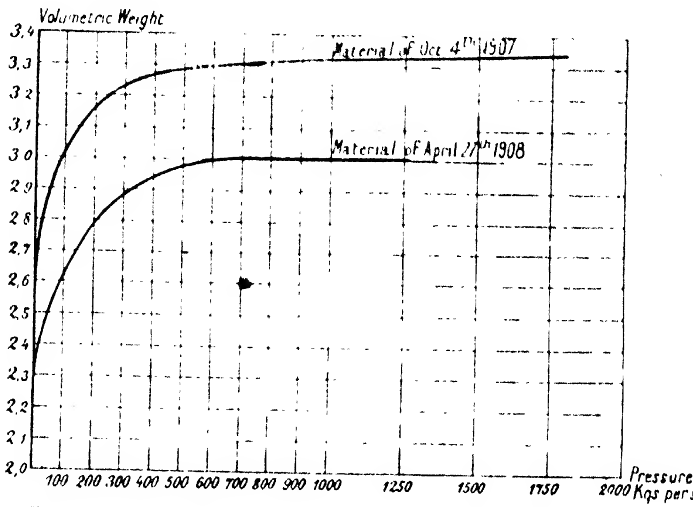


FIG. 22. -Compression Curves derived from the results of systematic pressure tests

Lurmann, l. o. Osnabrück and now of Berlin, the inventor of building blocks made from granulated blast-furnace slag and lime. Since then hundreds of machines have been delivered to fifty blast-furnace plants in and out of Germany almost solely for the production of slag stones.

All these presses produce large quantities of stone blocks for all kinds of building purposes, for front and back walls, foundations for heavy machinery, chimneys, and so on. In 1899 the construction of the press was considerably strengthened and altered so as to be suitable for working up the very different constituents of lime-sandstones. Since 1900 over fifty machines have been constructed for lime-sandstone factories. A few years ago the strength was further increased

to adapt the machine to ore briquetting, and the presses are now built in three sizes, weighing about 5000, 10,000, and 22,000 kgs respectively for the various purposes

This press differs considerably from all others with regard to the method of operation, since the pressure is not applied at right angles to the broad faces (25 × 12 cm. in German bricks) but at right angles to the narrow faces (25 × 6.5 cm.). Among other advantages for building purposes, this ensures that the bricks are all of the same height, thus preventing irregularities in the horizontal layer of a wall.

It will be best seen from the plan (fig 23) that the press operates an inner and outer stamp d_1 and d_2, which move towards each other

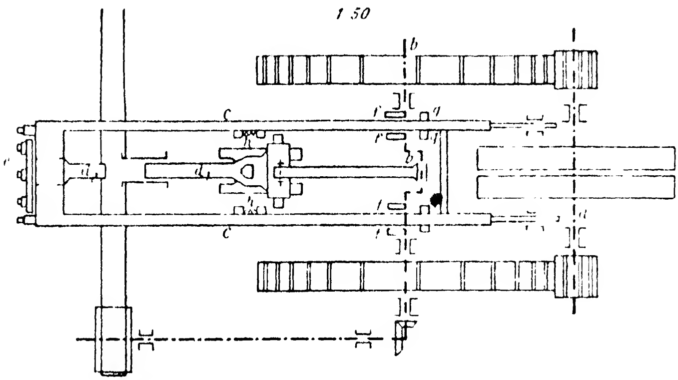


FIG. 23. Horizontal Press by Brück Kretschel & Co. Plan

during pressing, and exert a double-sided pressure on the material between them.

Drive is effected by belt transmission The press driving-shaft carries a fast-and-loose pulley, by means of which the press can be put in and out of action very rapidly. By means of two pairs of spur-wheels the power is transmitted to a simple crank-shaft b, running at 20 24 revolutions per minute The inner stamp d_1 is screwed to a cross-head set in motion by a connecting-rod from the crank-shaft. The outer stamp d_2 is considerably shorter than the inner one, and is fixed to the head e of the surrounding frame c

Forward motion of the outer stamp into the mould is obtained by two pairs of eccentrics keyed to the crank-shaft on both sides of each half of the frame Each eccentric piece strikes against a lug g—a half-moon-shaped piece of steel, which is not quite rigidly fixed to

the frame in order to absorb some of the shock of the blow. By the pressure of the eccentric against the lugs the surrounding frame is so moved that it draws the stamp into the mould. The return of this stamp is effected by the action of the cross-head on the framework. Towards the end of its stroke the cross-head strikes against the dash-pot springs h on two bosses on the framework and removes the outer stamp from the mould, while the long inner stamp is still carried on its forward stroke and pushes the finished briquette out. The eccentric

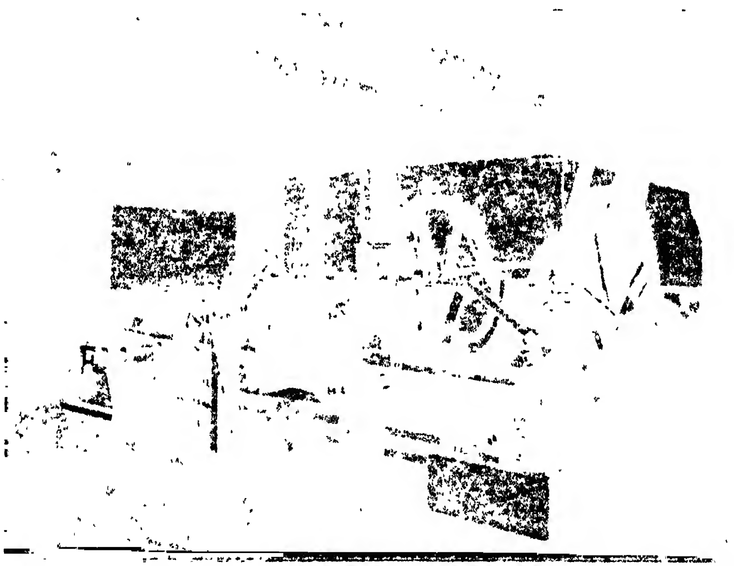


FIG. 24.—Brock, Kretschel & Co.'s Press. Front and side view from the right.

pieces are so fixed on the crank-shaft that they only press on the lugs, and again bring the outer stamp into the mould when the inner stamp has reached its dead point ready to begin its compression stroke. During the interval the mould is open for the introduction of fresh briquetting material.

A shaft, running parallel to the length of the machine is set in motion from the crank-shaft by means of a pair of bevel-wheels. This shaft operates the discharger by means of a double cam. The discharger forces the briquette, in case it should adhere to the press stamp, on to a band conveyor leading from the press to the loading waggons. The band is driven from a pulley on a shaft running the

length of the machine In order to prevent the briquetting materia being pushed out of the charging opening during compression th so-called sector is provided (figs 24 and 25). It takes the form of a cylindrical sector opened from the crank-shaft by means of a rod anc crank. Briquetting material can then fall from the downcomer intc the mould. Two heavy weights bear on eccentric pieces on the secto shaft and cause the sector to revolve until connection between moulc

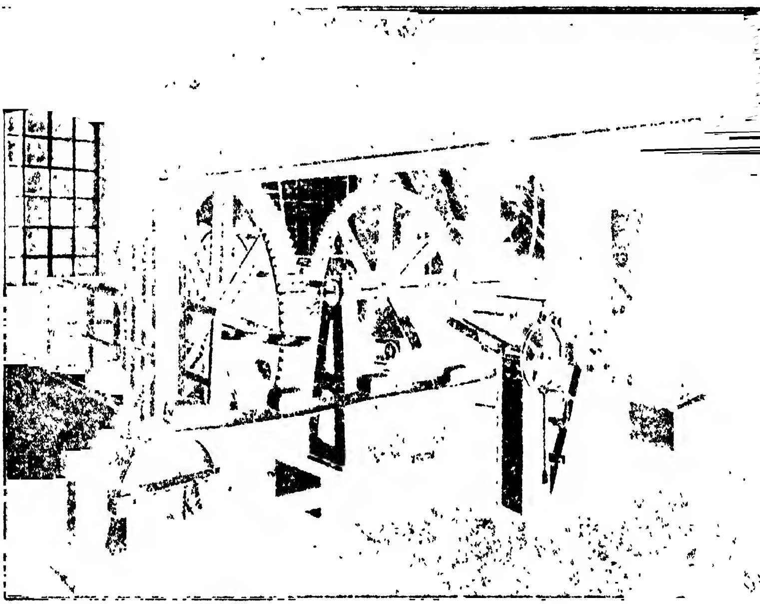


FIG. 25.—Brück, Kretschel & Co.'s Press. Front side, view from the left.

and charging apparatus is broken and the material held tight while a briquette is compressed.

The press stamps are hollow. At the press head of the inner stamp (fig. 26) is fitted an easily removable steel plate, fixed to the other end of the press stamp by means of a long bolt. Since the short stamp is not heated up so much by friction as the inner stamp, special steam heating is provided to prevent adhesion of the briquetting material to parts which are otherwise cold (fig. 27). Steam (at 3·5 atmospheres) enters the stamp through a rubber connection at the side, and is led as close as possible to the head by means of flues. The condensed water is removed by means of a second rubber connection.

Safety.—The front stamp rests against a cast-iron plate, the so-called breakage plate, at the head of the framework. When too

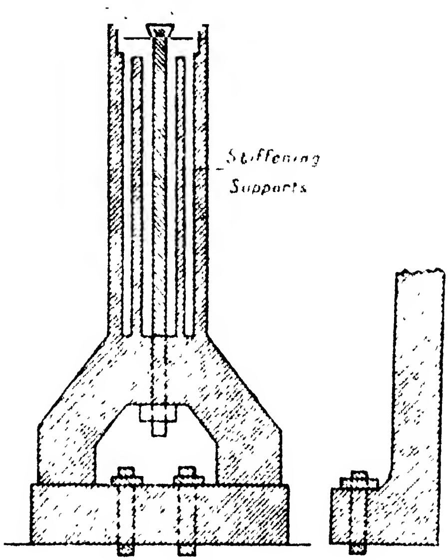


Fig. 26.—Inner stamp of the long press. Longitudinal section.

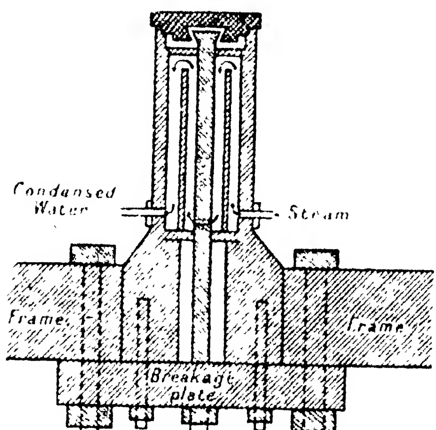


Fig. 27.—Outer heated stamp of the long press. Section.

high a pressure exists in the mould this plate fractures and protects the press from greater damage.

The mould is held together by four strong bolts, which break and

serve the same purpose as the breakage plate when too high a pressu[illegible] is generated in the mould.

A case in which three of the bolts broke just under the nut arose at certain ore-briquetting works during the treatment of too dry a materia[illegible] The following calculation shows the pressure ruling in the mould durin[illegible] the fracture:—

Section of broken bolts each of 3·3 cm. diam. .	= 8·5 sq. cms.
The tensile strength of mild steel is . . .	4500 kgs. per sq. cm.
The strength of the bolts therefore . . .	= 38,250 kgs. or 38 ton[illegible]
These bolts therefore break at	114 tons.

The pressure surface (= briquette surface) of the front inserted plate throug[illegible] which the pressure is exerted against the nuts is $20 \times 12 = 240$ sq. cm. Th[illegible] force of 114 tons acting on this surface works out at 478 kgs. per sq. cm. Sinc[illegible] the pressure in the mould is practically the same in all directions, the pressur[illegible] ruling at the time of the breakage must have been about 478 kgs. per sq. cm. while the press was built for a normal pressure of 300 kgs. per sq. cm.

A stamp has an average life of four months, while the inserted plates have to be renewed every eight or fourteen days. They are similar to those used in stone briquetting.

The following table gives information regarding weight, price, pressure, power consumption, and output of the various lime-sandstone and ore-briquette presses:—

	Weight.	Price.	Pressure in kgs. per sq. cm.	Power Consumption.	Strokes per minute.	Output per hour. No. of Stones.	Output per hour. Weight per Block.	Output per hour. Weight Total.
	kgs.	M.	kgs.	H.P.			kgs.	tons.
Lime-sandstone press.	abt. 10,000	8,000	130-200	...	17	1000-1100	3·6-6	3·6-6
Ore-briquette press .	,, 22,000	18,000	300 400	18	18	1000-1100	5-8	5-8

The pressure exerted by the lime-sandstone press has proved to be sufficient for certain ore briquettes if removed from the mould by hand. The highly desirable automatic removal of the bricks, however, demands a higher pressure (300-400 kgs.) in the ore-briquette press, and this renders possible a diminution of the binding material used. Thus an economy in labour and material is obtained. In the ordinary shape of brick the total pressure amounts to about 100,000 kgs.

The wear, which occurs almost exclusively in the moulds, varies very considerably with the various raw materials and the dependent methods of working. By using the renewable plates to be obtained

from the constructors, the costs of replacement are not usually more than 30 pf. per 1000 bricks.

The time occupied in changing the mould is about one hour. The ore-briquette press has found application on the large scale at the Ilseder Hütte and the Königshütte.

Revolving Table Press by Brück, Kretschel & Co. (figs. 28 and 29).—Like the previously described machine, this press was first constructed by the Osnabrück firm for the briquetting of lime-sandstones, for which purpose it was widely used. In 1908 it was built for the production of ore briquettes and similar materials under a double pressure of 125,000 kgs. It was provided with a special discharging piston and a pneumatic-hydraulic safety appliance.

The old lime-sandstone revolving table press (fig. 28) will first be described here. It works with a horizontal revolving table containing eight moulds, into which eight stamps can be driven.

Charging.—The briquetting material is scraped from the cylindrical charging pan (visible to the right) into the mould below by means of two wings on a vertical shaft. The height of the charge can be varied, and easily adapted therefore to the briquetting material in use. By repeated setting round of the press table the charged mould comes under the press plate of the upper abutment bolted to the exceedingly massive cross-head, which is secured by strong tie-bars.

Drive and Compression.—From the driving shaft at the left the power is transmitted to the main crank-shaft by two pairs of toothed wheels. The crank operates a beam below (not shown in the illustration), which, during its motion, presses against a stamp situated below the charged mould, raises the stamp into the mould from below, and compresses the charge against the upper fixed pressure plate. The pressure is therefore one sided. Unlike the long press, this press exerts pressure at right angles to the broad faces (25 × 12 cm.) of the brick.

Removal of the Block.—After each compression the table rotates through 45°, the stamps glide by means of rollers on a rising curve (as shown in fig. 28), and elevates the pressed blocks until they are pushed out of the moulds. The curve then falls again and the stamps glide back into the moulds, so that the latter can be refilled when it comes immediately under the feeding pan. The setting round of the table is effected by means of peculiar slots on the lower edge engaging with a cam driven from the main shaft by a pair of bevel-wheels. This drive serves at the same time for moving the wings in the charging box and the revolving brush (see fig. 28, to the right) in

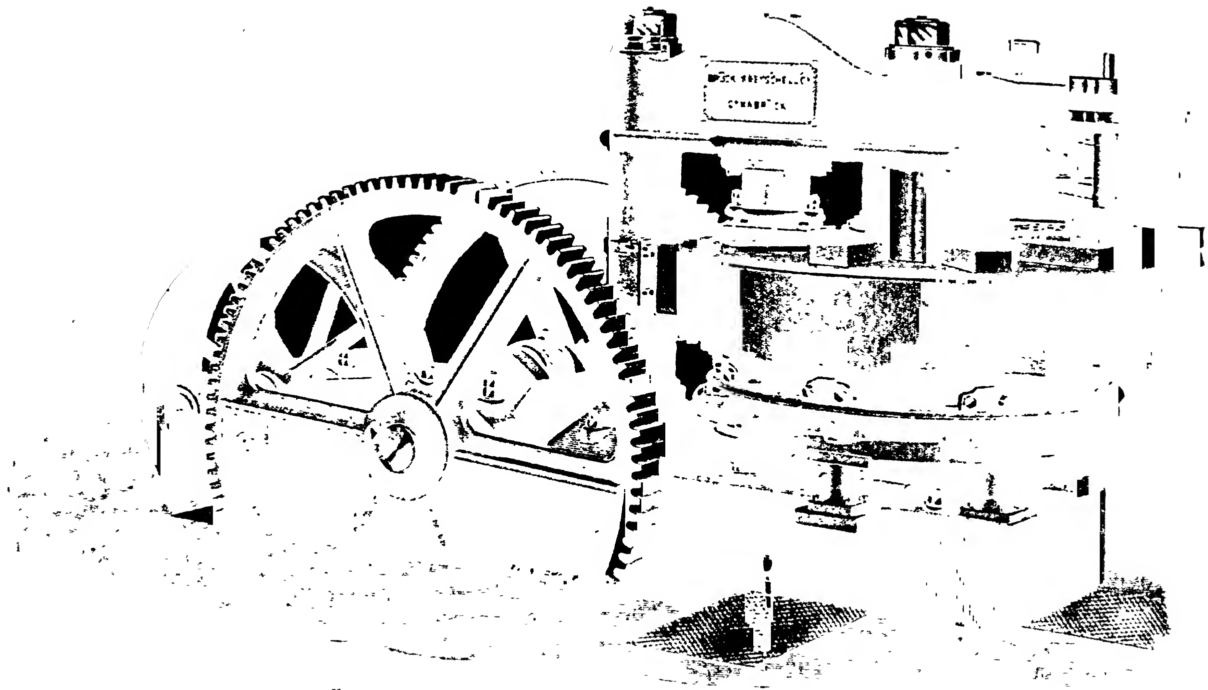


FIG. 28.—Bruck, Kretschel & Co.'s Revolving Table Press.

front of the feeding pan. The latter brushes the waste material lying on the table into a removable box at the side.

The stamp is provided with a second guide to prevent its getting out of truth and damaging the corners. The moulds are lined with hardened steel plates, which can be turned four times after partial wear in order to be completely used up.

Weight, price, power consumption, and output of the simple lime-sandstone press can be seen from the following table, which also contains the corresponding information regarding the new pneumatic hydraulic presses for ore briquettes, etc —

	Weight	Price	Pressure. Kgs per sq. cm	Pressure. Total	Power Consumption	Strokes per min.	Output per hour. No. of Bricks	Output per hour. Weight of each.	Output per hour. Tot
	kgs	M			H P.			kgs	ton
d simple revolv table press	abt 10,500	9,500		80 000	abt. 6	17	1000 1,200	3·6 6	3 6
w pneu hydr. revving table press	,, 22,000	20,000	400	125,000	,, 10	20	1000 1200	5 8	5 1

To special order the older press can be supplied as a double press for an output of 2000 bricks per hour. Two bricks instead of one are produced at each turn of the crank, and by this means considerable economies can be effected in installation and running costs, especially for large outputs.

Modern Pneumatic-Hydraulic Revolving Table Press (fig. 29). — The adaptation of this press for the considerably higher pressure (see above table) required in the manufacture of ore briquettes, etc., demanded a corresponding increase in strength of the construction of the press, and the provision of a special discharging apparatus consisting of a second piston. Above all, special safety appliances must be provided which were not necessary in the older revolving table press, since the variations in pressure and the overloading brought about by variations in filling the moulds were sufficiently compensated by the springing of those parts exerting the pressure.

Messrs Bruck, Kretschel & Company have completely solved the problem in a simple and original manner by means of their patent pneumatic-hydraulic safety arrangement.

The principal arrangement can readily be seen in fig. 29. The brick *a* to be compressed is contained in one of the twelve (instead of eight as formerly) moulds in the revolving table *b*, and is compressed by means of the piston *c* moved by means of the revolution of the crank

d and the raising of the large beam *e* revolving about the axle *f*. The latter is not rigidly attached to the frame *g* of the press, but is connected with the plunger piston *h* moving in the hydraulic cylinder containing oil under a pressure of about 135 atmospheres. This pressure is produced and maintained by means of compressed nitrogen contained in the cylinder *l*, similar to an ordinary carbonic acid cylinder, of 40 litres capacity. It can be hung to a wall or column near the press at a height of about 1 metre above the hydraulic cylinder, so that the nitrogen, which is lighter than the oil, is at the top of the cylinder. Sufficient oil is used to fill the lower part of the

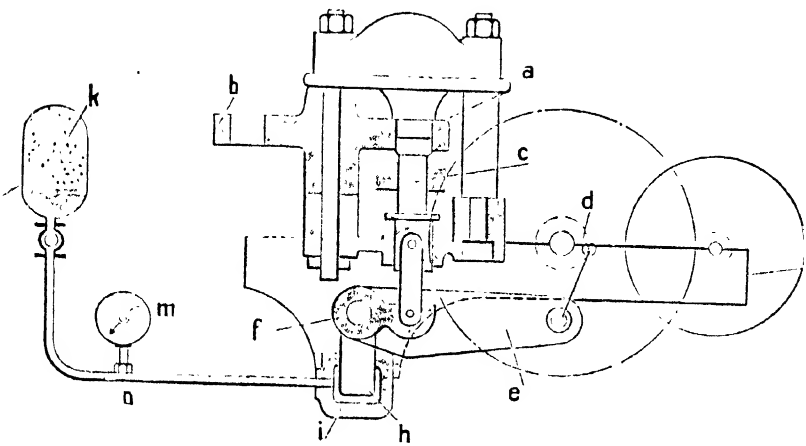


FIG 29 Diagrammatic sketch of the pneumatic hydraulic revolving table press by Bruck, Kretschel & Co. Longitudinal section.

cylinder, all the joints, etc., being in contact with oil, and kept tight by means of simple taps and packing.

If an abnormal pressure is attained owing to the introduction of more than the normal charge into the mould, the normal pressure of 125,000 kgs. is exceeded before the plunger of the press attains its highest position. At the moment this pressure is exceeded the pressure exerted by the nitrogen on the plunger *h* is overcome, and further motion of the lever *e* is taken up by this plunger, which is moved downwards and forces a certain quantity of the liquid out of the cylinder *i* through the pipe *n* into the cylinder *l*, where it slightly compresses the gas. When the pressure is removed from the briquette the plunger *h* is brought back to its original position by the pressure of the gas. Since none of the gas can be lost, one charge of the gas (which can be obtained quite cheaply) will last an unlimited time.

Important practical advantages from the point of view of output are intimately bound up with this safety appliance. By the introduction of a manometer m into the pipe line n the pressure can be controlled at each stroke of the press by slightly overcharging the mould each time by means of the arrangement provided for adjusting the charge. As a result a slight movement of the pointer of the manometer is caused during each stroke. Further, there is nothing to prevent the manometer being a registering one, or being provided with electric, optical, or acoustic signalling appliances, with the object of registering the pressure of each brick or briquette or of recording each overstepping of the normal pressure by means of signals.

In this way the same pressure and, what is more, the pressure for which the press was really built, can be attained every time. The new press, therefore, combines all the advantages of a hydraulic press (continual uniform pressure under control) and a lever press (simple mechanism and very high output).

The pressure at which the press works can be fixed and regulated within any predetermined limits up to the maximum pressure permissible simply by altering the pressure of the nitrogen in the cylinder.

Calculation of the Maximum Permissible Pressure of the Press. The plunger h has a diameter of 300 mm., equal to a sectional area of 706·9 sq. cm. On this area there is exerted the nitrogen pressure of 135 atmospheres (kgs. per sq. cm.), equal to a total pressure of 135 × 706·9 = 95,431·5 kgs. An oil pressure of 1 atmosphere, therefore, exerts a pressure of 706·9 kgs. on the plunger. According to the accompanying sketch (fig. 30) the effective arms I–II and II–III of the lever c amount to 375 and 1125 mm. respectively. The short arm I–II corresponds to the distance of the axis of the plunger h from that of the stamp e. The whole lever is alternately lifted up and down by the crank d engaging at the point III. On the up stroke the stamp is pressed into the mould above the point II. The point III can be taken as fixed; therefore, at the time of the maximum compression or the highest position of the crank. At this period the press stamp exerts a maximum pressure of 941 kgs. per atmosphere of oil pressure in the mould in consequence of the elevation of the lever. Since the products of the lever arms and forces are equal, this figure is obtained as follows:—

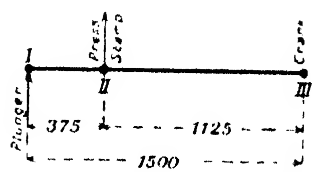


FIG. 30.—Sketch for the calculation of the maximum pressure permissible in the press.

$$150 \text{ cm.} \times 706{\cdot}9 = 112{\cdot}5 \text{ cm.} \times x.$$

$$\therefore x = \frac{150 \times 706{\cdot}9}{112{\cdot}5} = 941 \text{ kgs.}$$

Consequently, at an oil pressure of 135 atmospheres the total maximum permissible pressure in the press amounts to

$$135 \times 941 = 127,035 \text{ kgs.},$$

or, in round numbers, 125,000 kgs., which is the figure given above. This is exerted on the lower surface of the briquette, amounting to $22 \times 13 = 286$ sq. cm., so that the pressure per sq. cm. $= \frac{125,000}{286} = 437$ kgs. (or, more exactly, $\frac{127,035}{286} = 444$) per sq. cm., which equals 437 or 444 atmospheres.

Suitability of the Press. According to Bruck, Kretschel & Co., the pneumatic-hydraulic revolving table press is suitable for the preparation of lime-sandstones, slag blocks, cement stones, dry pressed clay bricks, for the after compression of clay bricks (clinkers), refractory fire and Dinas bricks, Trottoir bricks from clay and cement, etc., but is particularly suitable for the compression of ore briquettes.

Recently, two presses have been supplied to the new German briquette works at Salangen, in the north of Norway, for the briquetting of wet magnetic ore concentrates. Each press produces 1000 bricks ($19 \times 15 \times 8 = 2280$ cubic cm. in size) per hour. The specific gravity of the briquettes is 3.5, so that each briquette weighs 8 kgs., equal to a total production of 8 tons per hour, or 160 tons per day of twenty working hours.

The Sutcliffe Emperor Press (figs. 31-39)[1] (for preliminary and final two-sided compression). - This press is built by Messrs. Sutcliffe, Speakman & Co. of Leigh, Lancashire, and is widely and successfully used for the production of lime-sandstones, slag cement blocks, cement blocks, as well as for coal and ore briquetting. Its construction is similar to that of a toggle-lever press with a horizontally revolving mould table and partly resembles the Tigler and partly the Mazeline presses described in Vol. I. p. 169 and p. 116 respectively. Fig. 31 gives a view of the complete press, while figs. 32 to 34 show constructional details in section and plan. Fig. 35 shows the mould table with lining plate, and fig. 36 the older compression appliance.

The press is driven by a belt pulley (figs. 31, 32, 34) on the countershaft f_1, which sets the main crank-shaft f in motion. This sets the whole of the remaining movable parts in motion. Both shafts have

[1] G. Franke, "Mitteilungen über einige neuere schwedische Anlagen und Verfahren für Aufbereitung und Brikettierung von Eisenerzen und Kiesabbränden," *Glückauf*, Essen, 1908, No. 41.

their bearings in the frame of the massive press body. The mould table a is arranged at the side of the body and fixed to the hollow

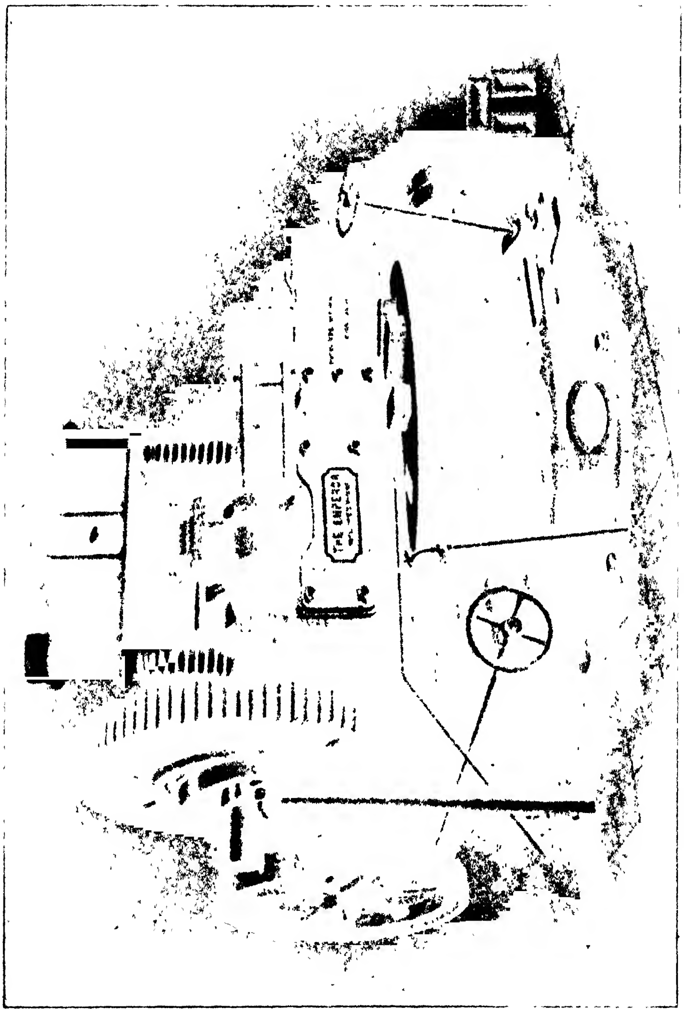


Fig. 8.—[illegible]

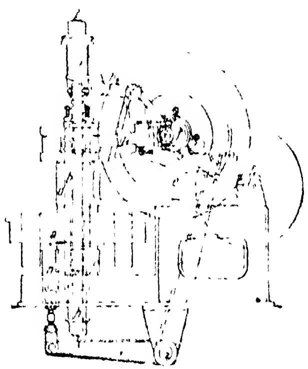
vertical shaft b. This is carried by the boss c on the base and above the table passes through the guide d fixed to the frame e.

The revolving table contains eight moulds of square shaped plan for ore briquettes and of rectangular section for lime-sandstone or cement

bricks. The moulds are made by the firm's patented method, and are lined with hardened steel plates. The plates are not bolted to each other, but are kept in position simply by the insertion of a peg. They can be easily removed and turned, so that they can be used twice over (figs. 34 and 35). The moulds and lining plates are made so accurately that each plate fits any of the moulds without trouble.

Charging the moulds is effected from the cylindrical feeding pan m (fig 34) by the propeller-shaped curved arm of a stirrer.

This charging arrangement has not proved itself specially suitable for purple ores, with the result that it has recently been supplanted at Helsingborg by another appliance which has proved itself to be much better.



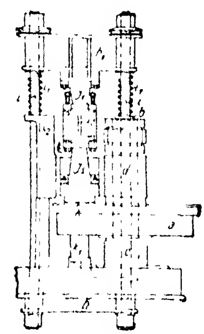


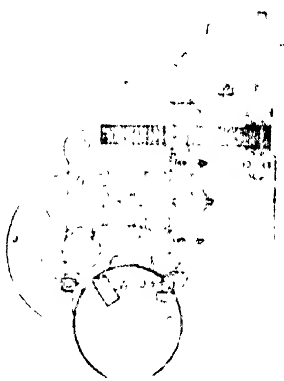
FIG. 32.—Side view FIG. 33.—Front view
of the Sutcliffe Press

The mass charged falls on to the renewable head plate of a stamp projecting into the mould. The stamp rests on a short movable track, which can be lifted or lowered by means of a lever operated by the hand-wheel seen to the left of fig. 31. In this way the filling of the mould and the pressure on the briquetting material placed in it can be regulated while the machine is working. The setting round of the mould table (figs. 32 and 34) is effected by means of the ratchet-wheel keyed on to the shaft b above the guide d and the spring-controlled pawl engaging with the teeth of the ratchet. When the crank g_1 of the main shaft moves backwards (to the right in fig. 34) the ratchet-wheel is pulled round, and on the return movement of the crank the pawl slides over the next tooth of the ratchet, and so on. By means of the setting round, the charged moulds with their stamps come under the compression appliance one after the other.

In the production of lime-sandstones, etc., the compression of the

mass consists of a preliminary and finished pressing, but in the preparation of ore briquettes there is only one operation, so that the appliances for the preliminary pressing are omitted. The appliances, however, are illustrated in figs. 33 and 36, and may be described as follows:—

Both compressions are carried out by means of the push bar i on the main shaft f and the toggle levers j_1 and j_2 with the assistance of the upper and lower cross heads k and k_1 and the two vertical tie bars or columns i, one of which is situated in the hollow shaft h. The frame formed in this manner rests through the intermediary of the strong spiral springs i_1 on the column i_2 from the base and on the head



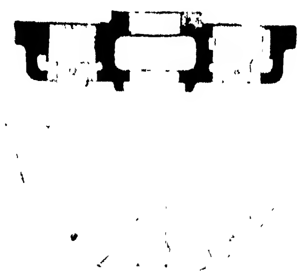


FIG. 34.—Plan of the Sutcliffe Press. FIG. 35.—Section and Plan of the Mould Table.

of the shaft h. The upper cross head is guided by means of the double link k_2.

During the forward motion of the push bar i the toggle levers bend and the cross-heads and columns sink, but on the return stroke the system of toggle levers is extended, and the cross-heads are lifted. At this moment both compressions take place. To the triangular-shaped toggle lever j_2 provided for the preliminary pressing is attached the wedge-shaped preliminary pressing stamp l. This is pushed into the mass from above, and presses it to the sides and corners of the mould, while the lower stamp l, resting on the gliding tract, exerts pressure from below. In the production of lime-sandstones and other artificial building bricks this operation is of special importance in producing blocks of as uniform a density as possible, but for ore briquettes, etc., it is unnecessary.

Simultaneously, the finished pressing is completed in the mould

situated immediately below the toggle-lever system. The stamp k_1, carrying the preliminary compressed mass, is lifted by the rising cross-head h, and presses the material against the pressure plate of the compression member l.

When the toggle-lever system is bent again by the forward motion of the bar j_1 the back rotating pin of the toggle lower lever j_2 rises and lifts the stamp l out of the mould, and the mould table, which is also burdened with a finished pressed briquette can be set round by the distance between two moulds. The preliminary pressed mass then comes into the plane of the toggle-lever system, and can be finished pressed in an exactly similar manner.

During compression the press appliances are steadily heated by means of steam led through piping above the mould table (fig. 31). The pressure exerted on each brick rises up to 150,000 kgs.

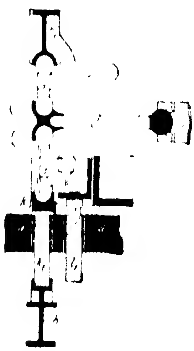


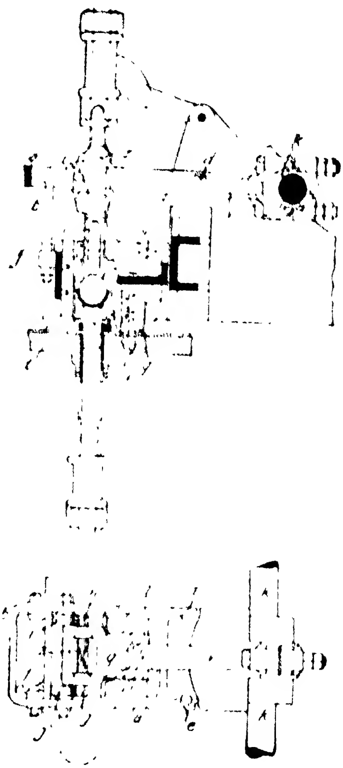
FIG. 36.—Section through the older press appliances.

Immediately after setting round, the finished pressed brick is taken up by the elevation of the discharging stamp n (fig. 32) operated by the bell crank lever n_1. The latter can turn about the axle n_2, carried below the frame base, and is moved up and down alternately as a result of the continuous movement of the roller n_3 at the top of the upper arm of the lever in the cam bolted to the outside of the large spur driving-wheel. The cam, which can be seen in fig. 31, is also keyed to the main shaft, and therefore revolves with it. The discharge stamp lifts the plunger in the mould concerned and elevates the pressed brick to the level of the mould table, whence it is removed by hand. When desired, the press can be provided with an appliance for automatically removing the bricks on to a band conveyor.

Recent Improvements.—An improvement introduced a short time ago consists in subjecting the bricks to equal pressures from above and below simultaneously. At the same time a safety arrangement is provided to ensure that the piston subjecting the material to the preliminary pressure and the stamps acting simultaneously in the final pressing enter and leave the moulds with such precision that no damage to the press is possible.

In the position depicted in fig. 37, the upper stamp o is just inside the mould in the revolving table and is supported by the lower stamp s and the compressed briquette. Now in order that the table can be

set round without interruption the upper stamp must be lifted out of the mould rapidly. This is effected by means of rollers *r* and *r*, carried in a frame *a* which are introduced into the path of the shoulders *g* and *h* of the pivot *z*. When the rotation of the crank *k* moves the connecting rod *e* to the left, the shoulders *g* and *h* glide over the rollers *r* and *r* and as a result of the angular joint with the upper plunger, the latter is lifted completely out of the mould. The frame *a* is held so that it can revolve round pins *d* and *e* on the frame of the machine at one end while the other end is carried by the bolts *b* and which can be adjusted at various heights by the support *r* fixed to the frame of the press.

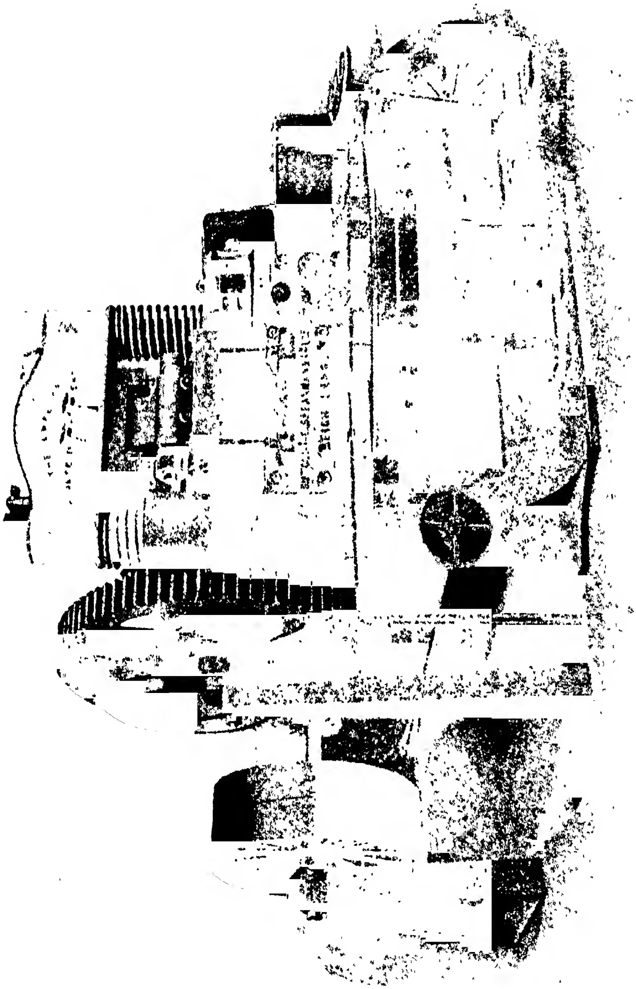


Figs. 37 and 38. Longitudinal Section and Plan of the Modern Compression and Safety Appliance.

When the compression is completed the material is first lifted up against the upper stamp *c* by the lower stamp *s* until it projects above the level of the table since the upper stamp can only have a short stroke because of the toggle drive. To prevent the overhanging material being pressed to the side by the returning upper stamp an auxiliary mould *p* is arranged around the upper stamp, and is kept in steady contact with the table by means of suitable springs or similar devices. Soon after the elevation of the upper stamp the table is set round until the next mould stands immediately below the upper plunger.

In order to ensure this being done accurately every time, a number of holes are made close to the edge of the table; further a spring-actuated pin *l* is attached so as to be capable of sliding to the shoe which operates the plunger *q*, and is itself moved by the pivot *y* of the lever *u*. On further rotation of the table the pin *l*, which has a

coned lower end, is pressed by the spring m into the next hole of th table, so that this is turned to the exact position in which the upper



press stamp has an uninterrupted entrance into the mould. The pin l is only drawn out of its hole again when the plunger q rises, and in this way damage of the press is effectively prevented.

The Duplex Emperor Press (illustrated) is built on the same principle as the simple Sutcliffe press except that it is larger and stronger, and produces two bricks at once.

The weight, output, and power consumption of the two presses are shown in the following table :—

Emperor Press.	Weight of the Press.	Max. Output per hour in No. of Bricks.	Power Consumption.	Price.
	kg.		H.P.	[illegible]
Simple press	[illegible]	[illegible]	[illegible]	up to [illegible]
Double press	[illegible]	[illegible]	[illegible]	„ [illegible]

Comparison of the Sutcliffe Presses with the older Drop Presses.—In the purple ore briquette works at Helsingborg, Sweden, to be described below, three Sutcliffe presses have been in use since 1906–07 in place of the older drop presses which were previously employed.

The report of the works management on the testing of the Sutcliffe presses, more particularly in comparison with the earlier drop presses, is very favourable. The Sutcliffe presses require only few repairs with the exception of those parts in constant contact with the ores. These, however, can be renewed very easily, more especially the lining and press plates. The drop presses, however, require quite considerable repairs even for the remaining parts, while the wear of the parts in contact with the ore is one and a half times to twice as great as in the Sutcliffe presses.

The latter yield briquettes whose thickness and hardness can be controlled during the operation; they are always uniformly dense, and have sharp edges; the bricks from the drop presses, however, show more or less irregular edges and are often permeated by faults which increase the wastage.

The following table shows the relations of the two systems towards one another as regards output, power consumption, and attendance :—

Press System.	Output: Per Minute: No. of Briquettes.	Output: Per Minute: Weight of each Briquette.	Output: Per Hour: No. of Briquettes.	Output: Per Hour: Total Weight.	Power Consumption.	Working Staff: Charging.	Working Staff: Unloading the Briquettes into the Waggons.
		kgs.		kgs.	H.P.		
Simple Sutcliffe Emperor Press	24	4	1440	5760	4–5	1	4
Drop presses	10	3½	600	2100	3–4	1	1

With a lower power consumption of about 1 H.P., the output of a drop press is only 30·6 per cent. of the total output of the Sutcliffe press. The difference of price in the two presses is very considerable, for while a drop press costs 3400 M. without freightage, the cost of a Sutcliffe press is approximately three times this figure.

Sutcliffe Emperor Presses have recently been brought into use for briquetting iron ores at the Koln-Musener Bergwerks-Akt.-Verein at Kreuzthal (Siegerland), and also in Spain at the Alquife Mines and Railway Company Ltd., Granada, and the Compania Minera de Sierra Menara.

The Couffinhal Press, for double-sided compression, with revolving table, built by the Maschinenfabrik Schuchtermann & Kremer, Dortmund, and

The Tigler Toggle Joint Press for double-sided compression, with fixed mould table, built by the Masch.-Akt.-Ges. Tigler of Duisburg-Meiderich, have already been dealt with under the briquetting of pit coals.[1] They are also suitable for ore and flue-dust briquetting, and have already been used for this purpose in specially strong designs for some years, the Couffinhal press at the Kertscher Eisenwerken (pressures up to 700 atmospheres) and other places, and the Tigler press at the blast-furnace works of the Gewerkschaft Deutscher Kaiser, Bruckhausen a. Rhine, for the production of cell-pitch briquettes under pressures of 400 to 500 atmospheres.

The Schüring Patent Toggle Lever Press,[2] built by the Zeitzer Eisengiesserei und Masch.-Akt.-Ges. of Zeitz, also appears to be equally suitable for ore briquetting, as also does the new simplified

Toggle Lever Press of Louis Schwarz & Company of Dortmund, which is to be used in the coal briquetting factory of the "Freie Vogel und Unverhofft" mine, in the course of construction at Horde.

The Dry Press of the W. Dünkelberg Maschinenfabrik of Steinhausen, Post Bommern (Ruhr), compresses from above and below in a fixed mould table. The pressure is, however, irregular, and is arranged so that its maximum value persists for 35 per cent. of a revolution. The presses are constructed in three different sizes, with 2, 4, and 6 moulds, and of 14,500, 28,000, and 33,000 kgs. total weight, principally for the briquetting of clayey shale, sand, slag sand, fireclay, and similar materials, and also for the briquetting of coals and ores. For this purpose the larger models are mainly used. Their outputs amount to

[1] Vol. I. p. 122 *et seq.*, figs. 48–55, and p. 158 *et seq.*, figs. 71–76.
[2] Vol. I. p. 169 *et seq.*, figs. 77 and 78.

8 to 10,000 kgs pit coal briquettes per hour with a power consumption of 5 to 8 H P

A six mould press is in operation for ore briquettes at the briquette works of the Krupp Friedrich Alfredhütte at Rheinhausen

The new **Humboldt-Surmann Press**[1] built by the Maschinenbauanstalt Humboldt, Kalk near Cologne is similar to the above toggle lever presses with regard to its method of operation Although primarily intended for coal briquetting it can be applied to ores etc without difficulty

The Hydraulic Press by Brink & Hübner[2] of Mannheim is used at the Königshütte for the briquetting of the cement copper obtained in the copper extraction plant by precipitation of the liquors extracted from burnt pyrites The very nature of the case demands the treatment of relatively small quantities of cement powder which are accumulated during a period of rest of the press so that they can be subsequently worked up in a short time The copper briquettes are in the form of small bricks and are sold as such

III. Compression with a very high End Pressure

Such a compression is effected during the operation of the Ronay method of briquetting (see p 36 *et seq*) The Ronay Hydraulic Press (figs 40-47),[3] built by the Maschinenfabrik Fritz Müller of Esslingen, is used for this purpose

The mechanism of the Ronay method of compression depends upon the knowledge that the increase in pressure at any moment of the operation is related to the amount of air in the material at that time and that this in turn depends upon the specific gravity porosity and degree of granulation of the material Instead of continual compression the pressure is effected in a series of steps

The greater the number of steps in the application of the pressure, the more does the pressure curve approach the ideal At the same time, the removal of air is promoted by the shocks occurring at each sudden increase of pressure

In fig 40 the curves show the manner in which this approach to the ideal is attempted or attained. The horizontal co ordinates give

[1] See the special pamphlet issued by the Humboldt Company.

[2] There are no published accounts of the construction of this press

[3] The description and illustrations are partly supplied by the inventor and partly by the "Allgemeinen Brikettierungsgesellschaft m. b. H. Berlin

the time in seconds, and the vertical co-ordinates the pressure in atmospheres. An ideal pressure curve is illustrated by *i*. The operation of pressing is to last 16 seconds, and the final pressure rises to 2000 atmospheres.

It will be seen that after 4 seconds (equal to one-fourth of the time of pressing) a pressure of only about 120 kgs. is applied; after 8 seconds, however, the pressure is about 360 kgs.; after 12 seconds, about 875 kgs., after 14 seconds, about 1300 kgs.; after 15 seconds, about 1575 kgs., and so on.

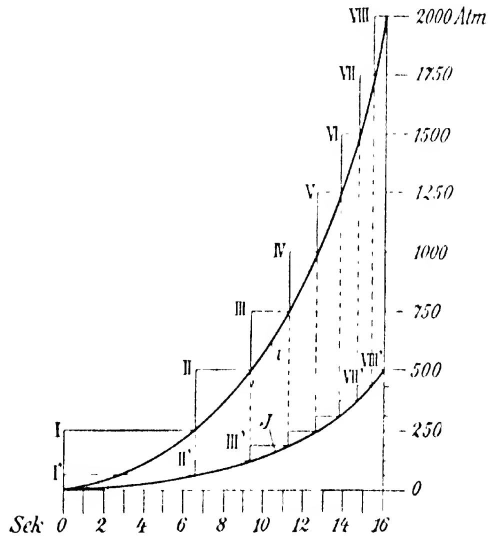


FIG. 40.—Approach of successive steps in the pressure to the ideal curve.

If, for example, the total pressure be divided into eight steps each of 250 atmospheres, as shown in fig. 40, it is evident that the periods of the stages of pressure become shorter as the pressure increases; thus stage I. is maintained for 6 seconds, II. for only 3 seconds, III. only 2 seconds, and so on, while stage VIII. only lasts for about a ½ second.

While the ideal curve *i* shows the pressures exerted on the effective area of the working stamp, and therefore the pressure exerted on the surface of the briquette, the curve *j* indicates the pressures exerted on the plunger by the water under pressure. In this connection the ratio between pressure on the briquette stamp and the hydraulic plunger is taken as four, so that a pressure of 500 atmospheres on the plunger is equivalent to a pressure of 2000 atmospheres on the briquette surface.

For practical purposes, however, the number of steps is limited, and usually four are considered sufficient.

The control of the various stages of the pressure is suitably attained by leaving the stop valve open in the delivery pipe from the corresponding accumulator and allowing it to be closed by the excess of pressure of the next higher stage in the compression. The mode of action of this method of control can be gathered from fig. 41 and the following description.

Valve I is opened by the control cam so that the first stage in the compression is started and maintained for a time determined from the curve J, while the rest of the valves are kept closed under the existing pressure. At the end of this period valve II is opened by a cam, and the higher pressure now prevailing in the delivery pipe closes valve I. In the same way control is effected of the third and fourth stages of the operation.

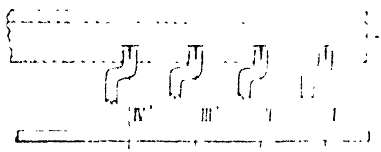


FIG. 41. Diagrammatic sketch of the valve control [illegible]

The installation is made up of four main parts:

1. A vertical pump provided with four low pressure cylinders, combined with a low pressure accumulator (fig. 42, left side).

2. A pressure transformer generally consisting of two multipliers, each connected with a water distributor.

3. The hydraulic press itself.

4. The driving motor with transmission to the various main parts, and consisting, in the plant illustrated, of a 50 H.P. electric motor.

The pump delivers water at 50 atmospheres pressure into the low pressure accumulator, whence it is delivered to the two multipliers. One multiplier delivers water at 250 atmospheres to the discharging cylinder, the other water at 150 atmospheres to the press cylinder, through the intermediary of the corresponding water distributor.

The press is made in two forms, of which the smaller one (figs. 42-44) only permits one operation during the turning of the revolving table, while the larger one (figs. 46 and 47) permits of two operations in the same time.

The smaller design will be considered first.

The revolving table *a* turns on ball-bearings; it has only three mould openings, of which *b* is being charged and subjected to pre-

liminary compression, while simultaneously *c* serves for the finished pressing and *d* for the discharge of the finished briquette The ring

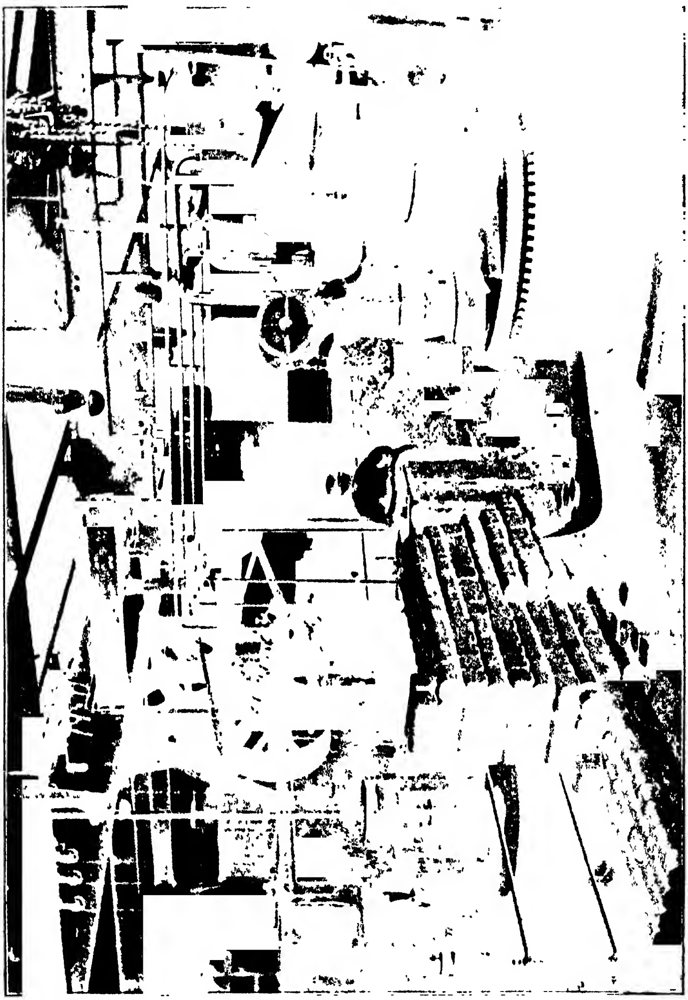
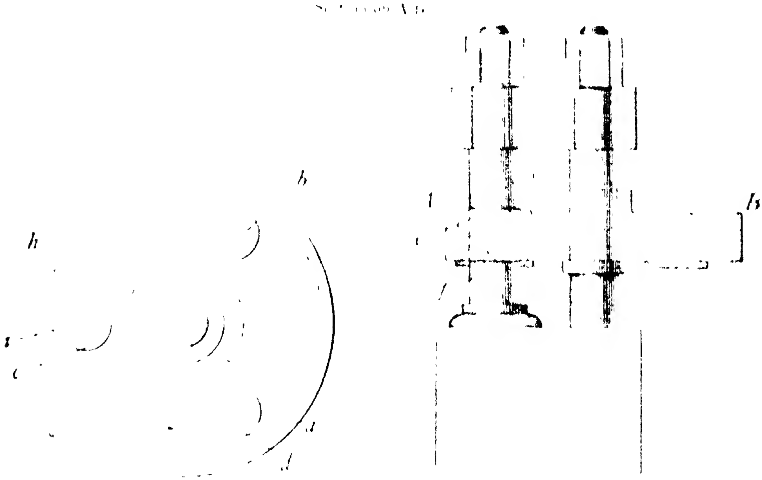


Fig. 42.—Bonay Hydraulic Briquette Pressing Plant.

h, situated below the table, is pierced at *c* and *d* to permit of the entrance of the stamp *f* and the discharging plunger.

Operation of Pressing In the mould opening *c* a special press mould *i* is inserted as an adjustable sleeve (figs 43 to 45) The stamp *f* is lifted by the water under pressure, driven into the mould *i* as described above, and presses the material previously introduced at *b*

against the fixed counter-stamp above. In this way the friction between the material and walls of the mould becomes so great that the mould *a* follows the stamp, glides upwards round the foot of the



FIGS. 43 and 44.—[illegible]

fixed upper stamp, while the material is further compressed. By this means the removal of air is promoted and the otherwise very great internal wear of the mould is considerably decreased.

Discharge of the Briquette.—After the completion of pressing the water pressure is removed and the stamp and lever return to their original positions, the table is set round and the briquette pushed up or down by the discharging stamp according to the arrangement. In fig. 42 it is pushed out below.

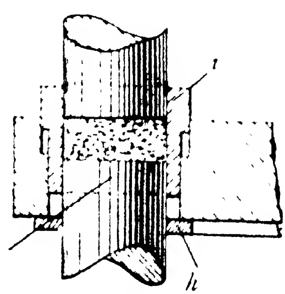
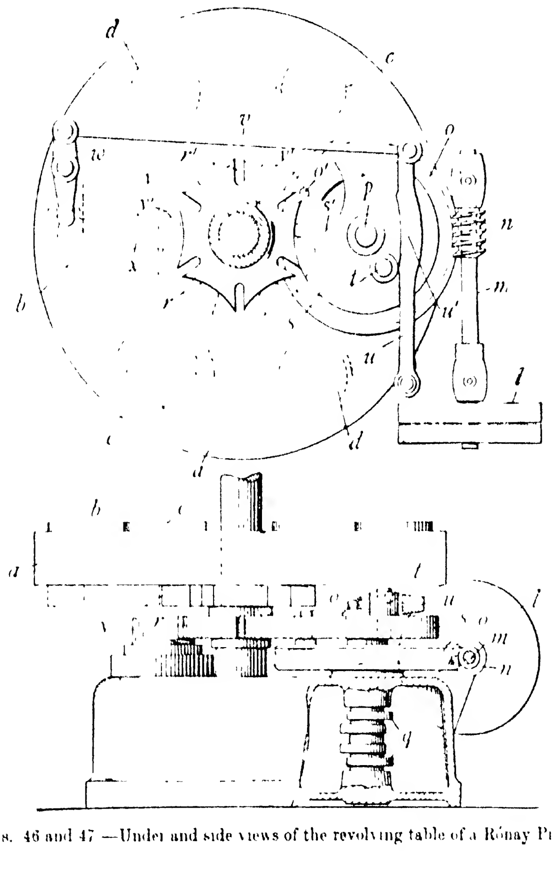


FIG. 45.—Illustrating the operation of pressure in a Rotary Press (magnified).

Another small design of the press is distinguished by having the mould table so arranged that it can be displaced along its axle to above the level of the foot of the counter-stamp when the friction in the mould becomes too great. Thus the adjustable sleeve can be dispensed with.

The double press (figs. 46 and 47) possesses six moulds for the simultaneous performance of two compressions, and so on.

The drive and method of turning the table can be gathered from the same illustrations. Drive is effected by means of the belt pulley l, the shaft m, the worm n, and the worm-wheel o. At the bottom of the vertical shaft p are situated the cams q for the stepped control of the plunger of the press, and above is the pulley s, having the part s'



FIGS. 46 and 47.—Under and side views of the revolving table of a Rónay Press.

cut away, and carrying a roller on a pin t operating against the curved portion u' of the lever u. The latter transmits the motion from the pin t to the fixing bolt x by means of the bar v and the double lever w.

A bolt o' fixed to the worm-wheel o projects through the cut-away portion s' of the disc s, and on each rotation of the wheel o engages in one of the radial slits r' in the star-wheel r, which is in this way

set round by a certain definite amount. (The double press has six and the single press three of such slots.) Firmly fixed to the star wheel is

Fig. 4[illegible]. Loading Ore Briquettes into Wagons.

the ratchet-wheel g into the spaces of which the bolt i fits and holds the table in a fixed position during operation.

Output and Power Consumption. The small press with three moulds completes the compression at approximately 1000 kgs., and

produces 4–5 briquettes per minute, or 240 to 300 ore and flue-d briquettes, each weighing 7 to 9 kgs., per hour. This is done at Friedenshütte (p. 38) with a power consumption of 40 H.P.

The double press produces about 400 to 500 briquettes per ho with a power consumption of about 60 H.P.

The Rónay press is specially suitable for the briquetting of all kin of iron and metal swarf under pressures up to several thousand atm spheres, and has been used for this purpose with success for sever years.

Briquettes produced by the Rónay press are illustrated in fig. (3 to 12), p. 21, and further information on this process is given in t section on Complete Plants.

The Astfalck Rapid Hydraulic Press built by A. Borsig, Berlin Tegel, is principally constructed as a very high-pressure forging pres for which purpose it is used in the Borsig workshops. It is, howeve well adapted to the production of iron and metal swarf briquette At the Borsig works a specially built Astfalck press with two stamp has been used exclusively for this purpose during the last two years.

Recently a rotating table press on the Astfalck system with si moulds has been built for the firm of Henschel in Kassel.

B. SUBSEQUENT TREATMENT OF BRIQUETTES.

If the briquettes are ready for immediate application after leaving the press, it is only necessary to convey them to the mixing floor of the blast furnace or other form of furnace to the storage sheds or to the loading ground when they are intended for transport.

Fig. 48 shows the loading of finished ore briquettes from two Bruck, Kretschel & Co. presses into railway waggons.

In certain methods of briquetting, however, it is necessary to subject the fresh briquettes to some form of subsequent treatment in order to harden or strengthen them and to render them as suitable as possible for application in the blast furnace (see p. 14).

I. Air Hardening.

In many cases it is sufficient to allow the briquettes to stand exposed to air for a long time when hardening results owing to evaporation and absorption of oxygen or carbon dioxide.

The bricks coming from the press are stacked in waggons so as to leave ample interspaces for ventilation. The waggons are then pushed

on to tracks in the open or under cover, and are left for the number of days or weeks requisite to complete the hardening after which they are conveyed to the place of application. Naturally this requires extended storage grounds and tracks but is nevertheless cheaper and much more advantageous from the point of view of appearance of the briquettes than stacking the briquettes into heaps of more or less considerable size and subsequently taking them up again, reloading into waggons, and so on.

II. Steam Hardening

Various methods of briquetting (see pages 15, 36, 57, 59, 60, 63 and 64) are completed by subjecting the pressed blocks to the action of superheated steam at 165° to 179° C. (6 to 9 atmospheres, upper pressure) for three to twelve hours. The object is generally to obtain hardening by the formation of lime silicate or hydrosilicate. The briquettes stacked on waggons are pushed into a long hardening kettle provided with rail tracks. When full the kettle is closed by means of steam tight end plates and steam at the above pressure is allowed to act on the briquettes for a predetermined period. The steam is then shut off, the kettle opened and the finished hard briquettes are removed. In order to obtain continuous working it is necessary to have two hardening kettles of ample proportion.

Hardening kettles of satisfactory construction and method of working are supplied by Brück, Kretschel & Co. of Osnabrück.

Hardening kettles are shown in the illustrations of many briquetting plant in the following section (Plate I).

III. Subsequent Heating with Flames, Waste Gases, Blast Furnace Gases, or Heated Air

This deals mainly with the drying of moist briquettes at temperatures of 150 to 500° C. but also partly includes hardening by the absorption of carbon dioxide (see pages 38, 44, 56, and 69). For this purpose channel drying ovens are specially suitable in the form applied for the drying of crude briquetted cement material. These installations are arranged either for direct heating of the briquettes by the hot gases or for indirect heating in which only hot air plays on the briquettes, which do not come into contact with the heating gases. Drying channels with direct heating are much less costly in installation because of the absence of the iron parts for the heating register, and are invariably preferred in the cement industry because of greater

output and lower cost of working, since the use of waste steam in the dryers is not permissible.

Moller & Pfeifer's System of Channel Dryers[1] has given excellent results in practice, and is widely used. Figs 49 to 51 illustrate a normal installation for direct heating. In this system the intolerable disadvantage of many channel dryers with direct heating, namely, that of high cost of repairs to the waggons, has been overcome by ensuring that the temperature of the iron portions of the trucks can never rise too high, and that moisture can be deposited on none of the iron parts of the furnace construction. A further advantage lies in the attainment of very high evaporative figures.

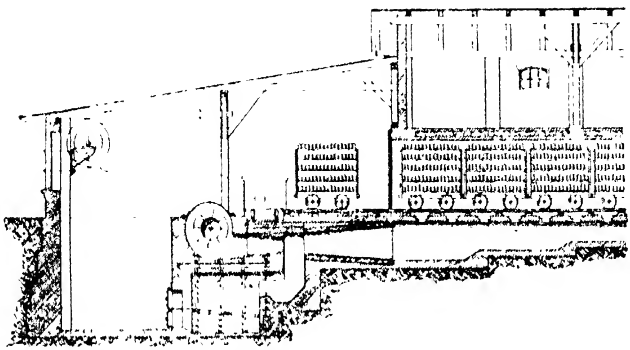


FIG. 49. Ejector firing of a Moller & Pfeifer channel drying plant. Longitudinal section.

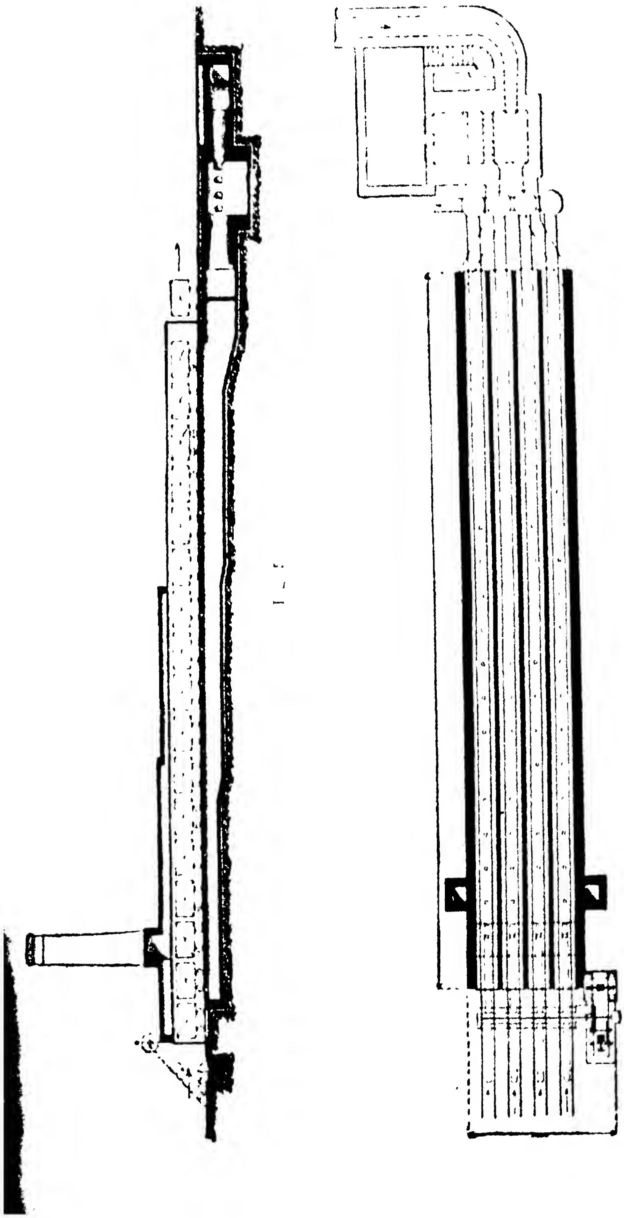
The drying channels are arranged one after the other in groups, and are completely bricked in and covered. Both ends are closed by massive iron doors.

Motion of the Briquette Waggons. The strongly constructed wrought-iron trucks (fig. 49), loaded with moist bricks laid on five shelves of the grid type, are drawn continuously through the channels arranged in series by means of an automatic winding arrangement. In this way the trucks pass slowly through hotter and hotter zones of the furnace until they finally emerge by opening the door at the back end of the channel.[2]

Heating.—The channels may be heated by the gases from a coal fire, by waste gases, or blast-furnace gases. In fig. 49 a system of

[1] See p. 97 *et seq.*

[2] In fig. 49 the back end of the channel with the firing is situated on the left, while in figs. 50 and 51 it is to be found on the right.



Figs. 50 and 51.—Four-track channel drying plant with M[illegible] & [illegible] [illegible] waste gases. Longitudinal [illegible]

coal firing, assisted by an ejector, is indicated at the far end of a group of channels. The ejector, driven by a current of compressed air from a fan, sucks air through the grate, and, by means of a mixing jet, mixes the fire gases with fresh air in order to prevent unmixed glowing gases from playing on the trucks The gas-air mixture is forced into the bottom flue, and rises upwards through holes in the floor into the channel containing the waggons, where it circulates round the briquettes, takes up moisture, and subsequently passes to the chimneys on both sides.

By regulating the ejector, the fresh air damper, and the admission and exhaust openings of the gas-air mixture, it is possible to adjust the temperature and moisture conditions of any channel at will.

In the drying plant illustrated in figs. 50 and 51, heating is effected by waste gases supplied through a subterranean flue at the left

IV. Burning or Sintering the Pressed Blocks.[1]

A treatment of this nature, requiring temperatures up to 1400° C., is principally necessary for briquettes made from argillaceous ores or friable brown-iron ores in order to drive out the three molecules of water of hydration, further, for magnetic iron ore briquettes which can only be thoroughly strengthened in this way, and also in some other isolated cases.

Burning can be suitably carried out in the well-known annular brick kilns or in channel ovens designed for working at high temperatures. Over the annular kilns, which have to be charged and discharged by hand, channel furnaces have the advantage of considerable economy in wages, since the briquettes can be loaded into trucks and passed through in the manner already described. The trucks, however, suffer considerably under the severe heating and often need repair and replacement.

The Grondal channel furnace is the one most frequently applied for burning ore briquettes. Its construction and operation (including the trucks used) is illustrated and dealt with in the description of the Swedish Magnetic Iron Ore Dressing and Briquetting Plant at Flogberget included in the next section.

[1] See pages 40, 51, 54, 65

SECTION VI

COMPLETE BRIQUETTING PLANTS.

In the following pages a number of typical briquetting plants are illustrated and more or less described in detail with reference to arrangement, operation and management.

A. TWO PRESS FACTORIES FOR THE PRODUCTION OF ORE BRIQUETTES AND THE LIKE, BY SCHUMACHER'S SILICA LIME METHOD (PLATE [illegible])

The production of briquettes from ore, etc., by Dr. Schumacher's patented method, already dealt with on pp. [illegible] *et seq.*, only differs from the preparation of lime sand stones in that the binding material consists of 3 to 10 per cent of lime and 1 to [illegible] per cent of finely ground quartz sand instead of the [illegible] to 8 per cent lime used in the latter process.

Ore briquette factories built by Brück, Kretschel & Co. of Osnabrück for the application of this process show the following typical arrangements:

Preparation of the Binding Material. Quicklime is brought in trucks along the track *a* (section AB and plan) and unloaded in the lime mill shed. It is shovelled into the stone breaker *b*, elevated by the elevator *c* and discharged into the ball mill *d*, from which it is caught below in special trucks, each of which are charged with a definite weight of the material.

Dust developed in the ball mill *d* is sucked off by a small fan and blown into a dust chamber.

The quartz sand is brought in on the track *h* and stored in the space in front of the tube mill *f* (plan). It is shovelled into a drying apparatus, is conveyed by an elevator *e* to the tube mill *f*, where it is ground to dust and automatically delivered into special waggons designed for the reception of definite weights.

Addition of Binding Material to the Ore.—The waggons containing the lime and sand, and the ore brought in tip-waggons along the track *h*, are conveyed to the upper storey by the lift *g*. A workman now tips the ore into the two loading hoppers *i* (section AB and CD), and adds to each charge one truck of quartz-meal and one truck of lime.

Admixture with the aid of Steam and Water.—As soon as the two mixing machines *k* (see fig. 18 on p. 104) have worked up their charges the trap-door of the charging hopper *i* is opened and the contents, which always contain the ore, quartz, and lime in the same proportions, fall into the preparation machine. Under the influence of steam and water and the heat from the jacket the lime becomes slaked, and an intimate mixing of the charge is effected. In about fifty minutes the operation is complete, the mixing machine is again opened at the bottom, and the material falls on to the stage *l* above the presses, and is shovelled into the charging hoppers of the presses by workmen.

Compression and Hardening of the Briquettes.—The presses *m* are of the type whose construction and mode of operation are described on p. 111 *et seq.* and illustrated by figs. 23 to 27.[1] Each press can easily produce 10,000 briquettes, each of 5 to 6 kgs. weight, in 10 hours.

The finished briquettes are taken from the presses and laid on iron hardening trucks arranged in series on the tracks *n*.

As soon as a waggon is full it is pushed on to a travelling platform running on the track *o*, and is transferred to one of the three hardening-kettles *p* (section CD and plan). Here the briquettes are hardened by subjecting to the action of steam at 8 to 9 atmospheres for about 8 to 10 hours, so that, including the time required for opening and closing the doors, each kettle can easily deal with two charges every 24 hours.

The hardened briquettes can be delivered immediately to the blast furnaces.

ESTIMATE OF COSTS[2] FOR THE FOREGOING TWO-PRESS PLANT.

Output.—For day and night working the output is 200 tons daily, or 60,000 tons of briquettes per year of 300 days.

[1] If desired, revolving table presses can be supplied instead of the "long" presses.

[2] According to figures supplied by Bruck, Kretschel & Co.

A Costs of Installation.

a) Buildings about 700 square metres at 40 marks	28 000 M	
For foundations boiler brickwork chimney labour of erection, iron work for supporting the mixing machinery	17 000	
		45 000 M
b) Mechanical appliances (according to tender)	141 200 M	
Electric motor with all accessories	12 000	
Carriage erection taxes and unforeseen costs	21 800	
		175 000
Total A		220 000 M

B Working Costs

(a) Sinking Fund

2 per cent of buildings and accessories (45 000 M.)	900 M
10 per cent of the mechanical appliances (175 000 M.)	17 500
Total	18,400 M

(b) Binding Materials.

Quick lime 5 per cent of the yearly output of briquettes (60 000 tons) 3000 tons at 10 M	30 000 M
Quartz sand 3 per cent. 1800 tons at 3 M	5 400
Total	35 400 M

(c) Wages

1 workman for grinding the lime	4.00 M.
1 " " " " sand	4.00 "
1 " on the bins	3.50
2 workmen on the mixing machine (one leading hand and the other as assistant)	7.50 "
2 " over the presses	7.00 "
2 " at the presses	8.00 "
4 " to lay briquettes on the hardening trucks	14.00 "
2 " attending the hardening kettle	7.00 "
1 foreman	8.00 "
Total per shift	63.00 M.

The total wage bill for 600 shifts amounts to 37 800.00 M

(d) *Steam Consumption.*

For 50 tons of ore briquettes (the output of a press in 10 hours) about 5000 kgs. of steam are required for the mixing machines and hardening kettles. Daily, therefore, for 200 tons of briquettes 20,000 kgs. of steam, corresponding to about 2800 kgs. coal (assuming an evaporative power of 7·2) are required. This corresponds to a yearly consumption of 300 × 2800 = 84,000 kgs., or 84 double loads of coal, which, at 110 M. per double load, gives a total cost of 9240 M.

(e) *Electrical Energy.*

On an average 160 nominal H.P., equivalent to 136 K.W., are required for 300 × 20 = 6000 hours per annum. This corresponds to 816,000 K.W. hours, which, at 3·5 pf. per K.W., works out at 28,560 M.

(f) *Small Materials, etc.*

Small materials, wear and tear, sundries, cost . . .	8600 M.

Summary of the Annual Working Costs.

(*a*) Sinking fund	18,400 M.
(*b*) Binding materials	35,400 „
(*c*) Wages	37,800 „
(*d*) Steam consumption .	9,240 „
(*e*) Electrical energy	28,560 „
(*f*) Small materials, wear and tear, and sundries .	8,600 „
Total **B.** - . .	138,000 M.

Consequently, the working costs per ton amount to $\frac{138000}{60000}$ = 2·30 M.

In addition, the license fees have also to be considered.

Remarks.—The figures taken for wages, cost of fuel, and electrical energy, and the price of the additions, correspond to average conditions ruling in Central Germany. By substitution of the figures ruling at the place of erection the final figures are more or less altered, but can easily be determined with the necessary accuracy on the basis of the above estimate of costs.

B. PURPLE-ORE BRIQUETTE FACTORY WORKING THE QUARTZ-MEAL LIME METHOD AT THE KÖNIGSHÜTTE, UPPER SILESIA. *

In 1907 a briquette factory was erected at the Konigshutte, next to the lixiviation plant in which burnt pyrites from Rio Tinto and else-

where are decoppered and desilverised for the purpose of preparing the large quantities of lixiviated purple ore for smelting in the blast furnace. The plant works Dr. Schumacher's lime sandstone method and has been built by Brück, Kretschel & Co. of Osnabrück, mainly on the lines of the two press factory already described.

Usually a mixture of 91 per cent. purple ore, 5 per cent. quicklime, and 4 per cent. fine sand is briquetted, but occasionally iron rich flue dust and magnetic concentrates are added.

Since the purple ore from the lixiviation plant contains on an average 20.5 per cent. of water, and since the most suitable content of water for compression is 11 to 12 per cent., about 35 per cent. of the purple ore must first be dried to 2 to 3 per cent. water in a Möller & Pfeifer drying plant. The ore dried in this way is then thoroughly mixed with the wet purple ore and the binding material in two preparation or mixing machines for thirty minutes. During this time a further reduction of the moisture content is effected through the agency of the jacket heated by steam at 6 atmospheres.

The mixture is pressed in two horizontal presses into briquettes, which are then hardened in two hardening boilers (16 metres in length, 2 metres diameter) under a steam pressure of 8 atmospheres for 10 hours, after which they have a compressive strength of about 100 to 130 kgs. per sq. cm.

Steam is generated in a Lancashire boiler of 90 square metres heating surface. At the same time this supplies a fireless shunting engine.

The machines and presses are driven by an electric motor of 154 H.P.

The daily output (in 10 hours) of briquettes amounts to about 22,500 bricks, or a total weight of 120 tons.

In the working year 1908-09 the average monthly output was 2615 briquettes.

The following workpeople are necessary for the simultaneous operation of the two preparation machines and presses:

(1) For conveying the ore:			
(a) To the drying plant			3 females.
(b) From the drying plant to briquette factory			3 ,,
(c) ,, lixiviators			6 ,,
(2) On the drying plant		2 males	1 female.
(3) ,, lift		1 male	0 females.
(4) ,, storage bins		0 males	4 ,,
(5) ,, preparation machines		2 ,,	0 ,,

(6) Charging the presses	. . .	0 males	6 females.
(7) On the presses	. .	8 ,,	0 ,,
(8) ,, hardening boilers	.	3 ,,	0 ,,
(9) ,, steam boiler	. .	2 ,,	0 ,,
(10) ,, electric motor	. .	1 male	0 ,,
(11) ,, lime mills .	.	1 ,,	0 ,,
(12) ,, sand mill	.	1 ,,	0 ,,
(13) On repair work		2 males	0 ,
(14) Loading briquettes		0 ,,	8 ,,
	Total . .	23 males	31 females

In addition there is the foreman.

With regard to the application of the briquettes and their favourable influence on the working of the blast furnace, the Konigshutte works management reports as follows:—

"On an average, the quantity of briquettes worked up with a normal charge amounts to about 15 per cent. The furnace works more rapidly, the pig iron produced is of much greater uniformity in composition, and the coke consumption is diminished by an amount equal to the increase in the ore charged. The flue dust has become poorer in iron. Although the quantities produced have not been actually measured there is undoubtedly a diminution"

C. ONE- OR TWO-PRESS FACTORY WORKING THE GERMAN BRIQUETTING CO.'S METHOD AT THE FRIEDRICH-WILHELMSHÜTTE (fig 52).[1]

The Sieg-Nassauische Huttenaktiengesellschaft at the Friedrich-Wilhelmshutte, Sieg, has erected and worked since 1907 a briquette factory (see fig. 52) for the application of the method of the Deutschen Brikettierungsgesellschaft, Altenkirchen (p. 61).

The ores to be briquetted (usually fine-grained, roasted Siegerland spathic ore) and the binding materials are carried to the upper storey by the lift A and shot into the bunkers B and C.

Admixture of the ore and binding material is effected, first by the distributing table D and the worm E, which latter discharges the material through the downcomer F into the edge-runner G. Here, and in the adjoining mixer, the material is thoroughly mixed and moistened, after which it is conveyed by the elevator H to the Surmann press J. The latter works under a pressure of 400 atmo-

[1] *Stahl und Eisen*, 1908, No 10, p 324

spheres, and can produce 1000 briquettes per hour. Provision has been made for a second edge runner and another press.

After stacking for hardening the briquettes require no further treatment. They are cylindrical in shape 160 mm in diameter 150

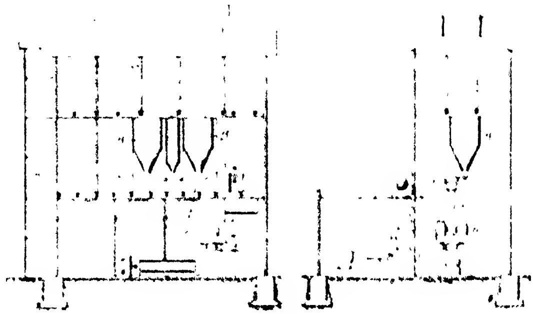


Fig. 52.—[illegible]

mm high and when worked up from roasted Siegerland spar they weigh 7 kgs. Consequently 7 double loads or 70 tons can be produced in a 10 hour shift. Favourable opinions are expressed regarding the application of briquettes and are reported on p. 62.

D. TWO PRESS FACTORY WORKING THE SCORIA PROCESS (figs. 53-55)

The arrangement of a two press factory for working the Scoria process (Scoria Gesellschaft, Dortmund) see p. 63) can be gathered from the accompanying diagrams.

By means of a lift the truck loads of ore or flue dust are conveyed to the top storey and emptied into storage hoppers by means of a rotatory tipper, while the granulated blast furnace slag (slag sand) to be used as binding material is carried up in the same way and supplied to a slaking drum where it is treated with superheated steam prior to being discharged into a storage hopper.

Below the hoppers are situated the revolving distributors, whose plates stand about 100 mm below the lower edges of the hopper. The material spreads itself uniformly on the table, and by means of accurately adjusted scrapers pre-determined quantities of ore (or flue dust) and slag sand are supplied to the central revolving table from the respective distributors on either side.

From the central table the mixture is scraped into a worm conveyor, which thoroughly mixes and supplies it to a triple edge-runner mill.

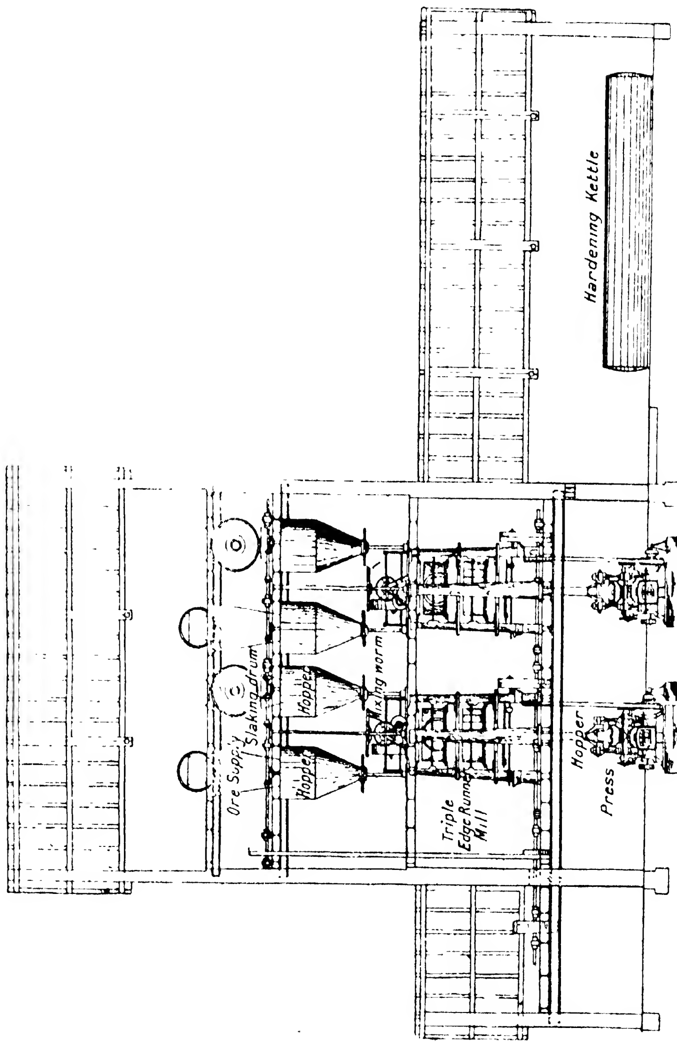


FIG. 53.—Longitudinal section of a two-press factory working the Scoria process.

In this way a very intimate mixture is produced and supplied to the two Dunkelberg presses through a wooden hopper.

The briquettes produced are loaded on to trucks and conveyed to the hardening boilers by the travelling platforms and the tracks.

They are then subjected to the action of superheated steam for 7 to 10 hours when they are ready for use. For convenience the hardening boilers are made as long as the travelling platforms.

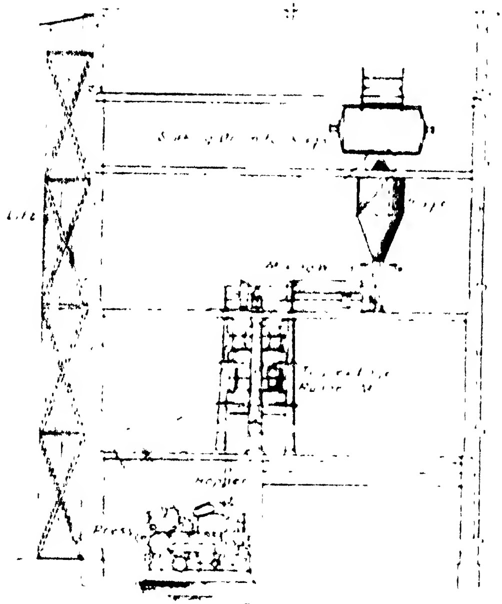


Fig. 54.—Cross-section of a two-press Sand-briquette factory.

ESTIMATE OF COSTS.[1]

The output of the foregoing plant, working day and night shifts (20 hours), amounts to about 40,000 briquettes per day, or about 12,000,000 per year of 300 working days. Each briquette weighs 4 to 7 kgs., according to its shape and specific gravity, so that the total weight is about 48,000 to 84,000 tons per annum.

In the case of the exclusive use of slag sand, as described above, the whole of the binding material is available without cost as a waste

[1] *Stahl und Eisen*, 1908, No. 10, p. 235.

product of the blast furnace, and under these conditions the following represent the costs of installation and production:—

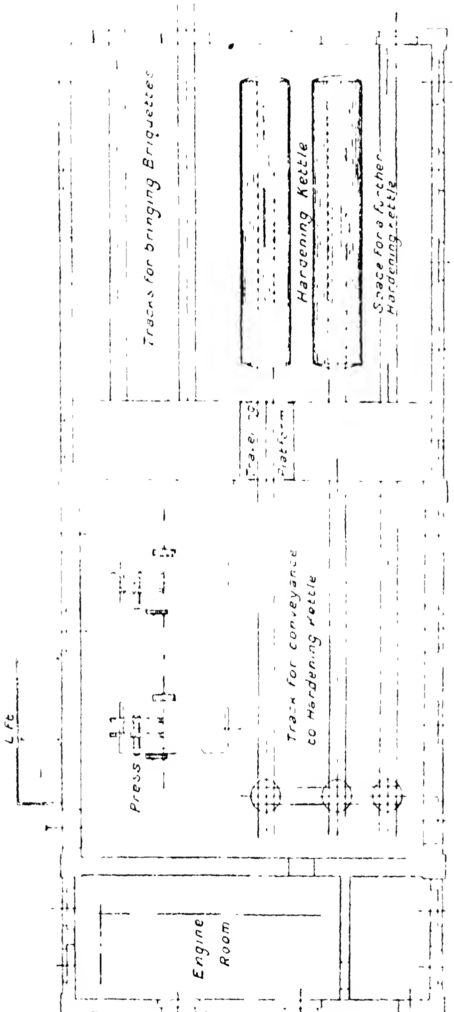


Fig. 55.—Plan of two-press Scoria briquette factory.

A. Costs of Installation.

(*a*) Buildings	20,000 M.
(*b*) Mechanical appliances (according to special tender)	150,000 „
Total **A**. . . .	170,000 M.

B Costs of Production

(a) Sinking fund and interest

10 per cent. of the cost of installation (170 000 M.) — 17 000 M

(b) Wages

For the day and night shifts there are necessary

2 workmen for the steam engine and boiler			
2	emptying the slag sand		
2	the mixers and edge runners		
8	the presses		
8	as labourers		
22 workmen at 4 M. per day for 300 days		26 400 M	
and 2 managers at 2400 M. per annum		4 800	
	Total		31 200 M
(c) Steam consumption			6 000
(d) For renewals			6 000
(e) Sundry requirements (inclusive of power costs, oil, cleaning waste, etc.)			5 800
	Total B		66 000 M

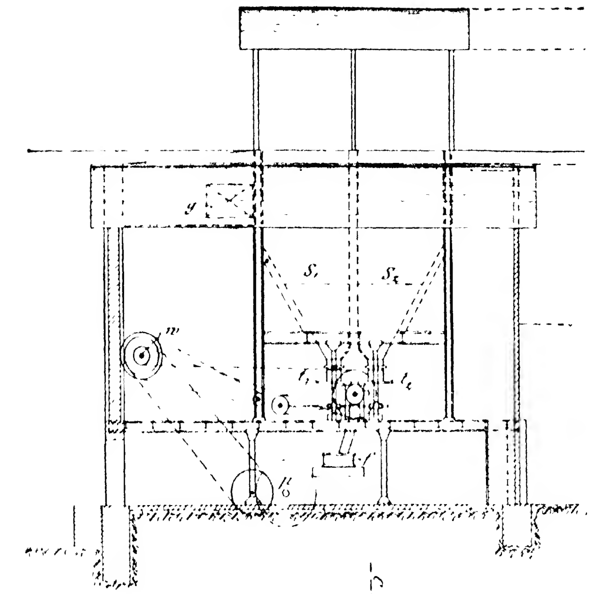
This gives a cost of production of [illegible] M. per 1000 briquettes, and assuming a maximum weight of 7 kgs. and a minimum weight of 4 kgs. per briquette the cost of production of a ton of briquettes varies between [illegible] and [illegible] (0·80 – 1·40 M.).

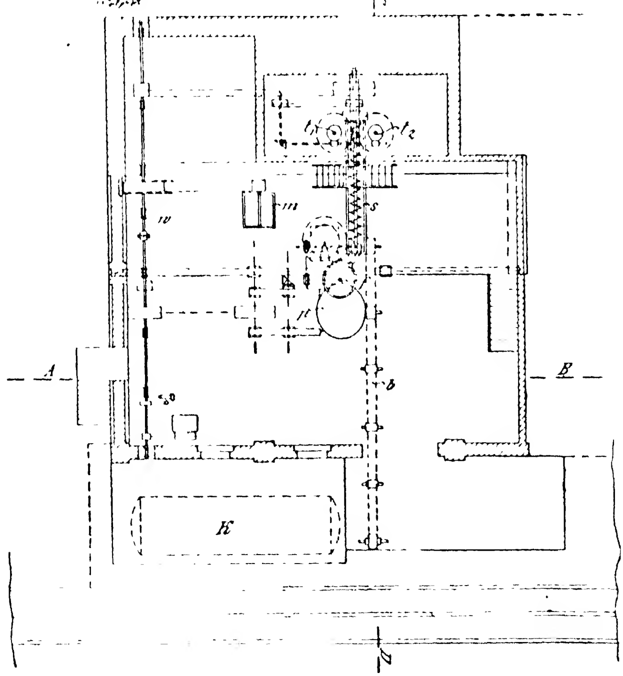
If, as in the case of the briquette factory of the Friedrich-Alfredhütte at Rheinhausen, a bond consisting of 4 per cent. slag sand and 4 per cent. quicklime is used for binding flue dust, the costs of production are naturally increased by the cost of the added lime.

E. FLUE-DUST BRIQUETTE FACTORY WORKING THE MAGNESIUM CHLORIDE PROCESS AT DÜDELINGEN (figs. 56 to 58)

This plant was built in August 1909 by Bruck, Kretschel & Company for the Eisenhütten Aktienverein, Düdelingen. It is situated on the slope of the ironworks' slag heap advantage being taken of the differences in level to dispense with lifting appliances, such as elevators, etc.

Section at A B.





Plan.

Figs. 56 and 57. Flue-dust briquette factory at Dudelingen working the magnesium chloride method.

The method used, Dr. W. Schumacher's magnesium chloride method has already been dealt with on p. 35.

The flue dust is conveyed in tipping waggons along a pre-existing track and shot into bunkers S_1 S_2 of about 40 cubic metres capacity. Both bins are provided at the bottom with revolving scraper tables t_1 t_2, which cause definite and constant quantities of flue dust to fall into the mixing and moistening worm trough s.

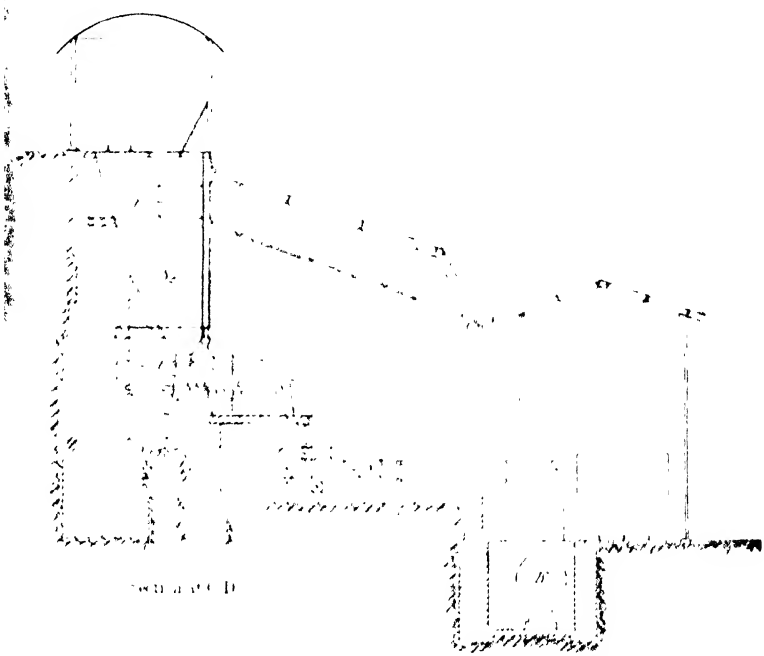


FIG. 58.—Flue dust briquette factory at Dielingen working the magnesium chloride method.

The magnesium chloride liquor is conveyed in tank waggons and emptied into boiler-shaped containers k, situated below the floor of the factory. From the tank k a pump discharges the liquor into a vessel g situated about half-way up the bunker. The liquor is thence conveyed by a pipe to the trough s in definite quantities (1 per cent. $MgCl_2$ to 99 per cent. flue dust) regulated by a screw cock. In addition, the flue dust is also water-sprayed from a rose connected with the water-pipe.

The briquetting mixture thus prepared falls from the front end of the worm trough s into the charging box of a large hydraulic-

pneumatic revolving table press *p* of the latest type made by Bruck Kretschel & Company, as described on p. 119. Here it is compressed

Section A B.

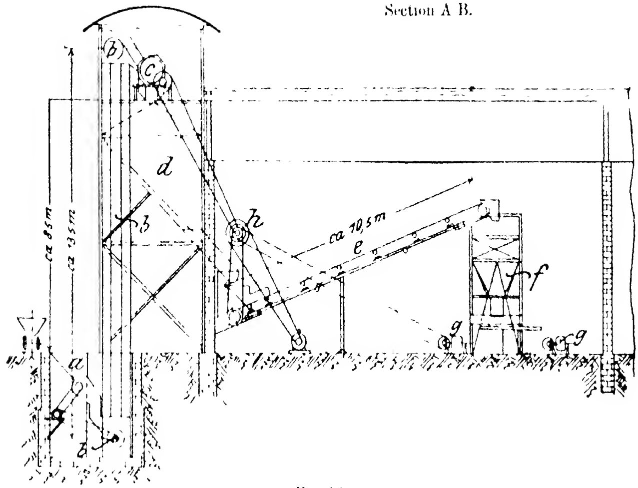


Fig. 59

Plan.

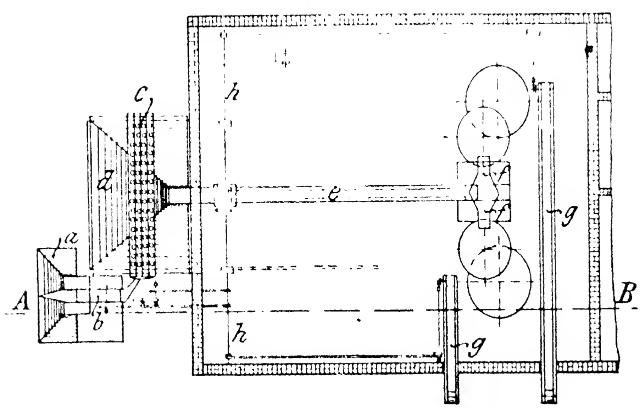


Fig. 60.

FIGS. 59 and 60.—Longitudinal section and plan of a two-press factory operating the Ronay Method.

to briquettes of about 5·5 kgs. in weight, which are automatically removed from the press by a band conveyor *b* and carried to the loading track, where they are removed into trucks. In 10 to 24 hours the briquettes are quite ready for smelting.

The whole plant in which provision has been made for a second press, is belt driven by a motor *w* and the main shaft *a*. The installation is very simple and works exceedingly well.

F. TWO PRESS INSTALLATION FOR THE RÓNAY METHOD (figs. 59 and 60)

According to the plans of the Allgemeinen Brikettierungsgesellschaft m. b. H. Berlin the plant for working the method described on p. 36 *et seq.* by two hydraulic Rónay presses (pp. 131 *et seq.*) is arranged as follows.

The crude ore passes from the feeding hopper *a* by the elevator first to the drum sieve *c*, which sorts out the coarse ore, deposits it on a chute, and this in turn carries it away for direct smelting, while the fine ore falls into the large bunker *d*. From this it is drawn when required on to the band conveyor *e* and shot into the charging hoppers *ff* of the presses. The belt conveyors *gg* remove the compressed blocks for loading.

The hydraulic appliances of the presses (pump with pipe lines, accumulators, multipliers and distributors) are situated on those portions of the press room left blank in the diagram.

ESTIMATE OF COSTS

I. Rónay Briquetting Plant with a Press for 600,000 kgs Pressure

Output per annum 30,000 tons of finished briquettes under a pressure of 1000 atmospheres are produced in 300 days of 20 working hours. The specific gravity of the finished briquette is 2.5.

A. Costs of Installation.

1	Press inclusive of installation and carriage	65,000 M.
2	Transmission, belts and conveying appliances inside the press room	10,000 ,,
3	Possible auxiliary appliances (mixers, driers, sieves)	20,000 ,,
4	Buildings and foundations	25,000 ,,
	Total **A**.	120,000 M.

B. Costs of Working.

1. Sinking Fund and Interest—

Machines, 10 + 5 per cent. of 95,000 M. =	14,500 M.	
Buildings, etc., 5 + 5 per cent. of 25,000 M. =	2,500 „	
Total		17,000 M.

2. Wages—

Daily in two shifts.	2 machine attendants at 6·00 M. =	12 M.	
	2 fitters at 4·50 M. =	9 „	
	6 labourers at 3·50 M.	21 „	
	Total . 300 ×	41 M. =	12,600 „

3. Power—

With a power consumption of 35 H.P., 35 × 20 × 300 = 210,000 at 3 pf. per H.P. hour . . . 6,300 „

4. Materials and Repairs—

10 per cent. of the installation costs under 1 and 2 . . . 7,500 „

5. Sundries and Completion . . . . 8,600 „

Total B. . . . 52,000 M.

Consequently the costs of production per ton = $\frac{52000}{10000}$ = 1·80 M.

II. Installation with a Powerful Rónay Press for a Pressure of 1,000,000 kgs.

This plant has an annual output of 50,000 tons of briquettes, with a power consumption of 60 H.P.

The installation costs are raised to 150,000 M., and the working costs are raised to 61,250 M., but the costs of production are nevertheless reduced to $\frac{61250}{50000}$ = 1·25 M. per ton of briquettes.

G. BRIQUETTING PLANT FOR THE GRÖNDAL METHOD.[1]

I. General.

In Sweden the enrichment of poor iron ore deposits (formerly considered as not sufficiently valuable to be worked) by magnetic concentration and briquetting or sintering has made considerable progress in the last few years.

[1] G. Franke, "Mitteilungen über einige neuere schwedische Anlagen und Verfahren für Aufbereitung und Brikettierung von Eisenerzen und Kiesabbränden," *Glückauf*, Essen, 1908, Nos. 40 and 41. See also p. 41 *et seq.*

According to a report of the Royal Commercial College of Stockholm,[1] the position of the Swedish iron-ore supply, concentration and briquetting in the year 1906 was as follows:—

Iron-ore Supplies			Iron-ore Concentrates			Briquette Production		
No. of Mines Worked	Quantity	Value at Works per Ton	No. of Works	Iron-ore Concentrates	Concentrate Produced	Quantity	Value	Marks per Ton
				[illegible]	[illegible]	tons	M.	
3[illegible]	4,[illegible]	6.[illegible]7	18	25[illegible]	1[illegible]	[illegible]	1,4[illegible]	1[illegible]

After suitable pulverising the ores were mainly concentrated by magnetic ore separators of the Wennstrom, Forsgren, Erikson, Grondal, Ekmann, Markman and other systems.

For finely pulverised magnetic iron ore the recent repeatedly improved Grondal method of preparation with subsequent compression and calcination in a channel oven has found almost universal application. The method is also applied to the treatment of purple ore and other powdered materials in large quantities. Both the most important Swedish briquetting plants, that at Herrang and the one at Helsingborg, apply the Grondal method. Of the total Swedish briquette production of 78,000 tons in 1906 Herrang was credited with 26,453 tons from magnetic iron ore concentrates and Helsingborg with 21,171 tons from purple ores.[3]

For some years the Grondal patents have been operated, and new plants designed by the "Metallurgiska Aktiebolaget" of Stockholm, of which firm the inventor, Gustaf Grondal, is a member.

According to information supplied by this company, the following works were using this system in 1906 in Sweden and other countries:—

[1] *Glückauf*, Essen, 1907, p. 1358.

[2] 92.5 per cent. of the ore production consists of black magnetic iron ore and 7.5 per cent. of kidney iron ore.

[3] The briquette production of Helsingborg would have been much higher had not a great strike put the works out of operation for a long time.

TABLE

Iron Ore Concentration and Briquette Works using the Grondal Method in 1906.	Yearly Output: Crude Ores	Yearly Output: Concentrates and Purple Ore
Sweden	tons	tons.
Persbergs Grufveaktiebolag, Concentration . .	2,500	
Pryllshytte Grufveaktiebolag, ,,		15,000
Strässa Anrikningsverk, ,, .	8,000	
Klacka Lerbergs Grufvebolag, ,, .		5,000
A. B. Bredsjö Bruk, Concentration and Briquetting	10,000	
Herrängs Grufaktiebolag, ,, ,, ,,	50,000	
Guldsmedshytte Aktiebolag, ,, ,, ,,	60,000	
Uttersbergs Bruks A. B., ,, ,, ,,	12,000	
A.-B. Spräckla Grufvor, ,, ,, ,, .	10,000	
Luleå Jernverks A. B., ,, ,, ,,	60,000	
Flogberget, ,, ,, ,,	23,400	
Helsingborgs Kopparverks Aktiebolag, Briquetting		10,000
Sandvikens Jernverks Aktiebolag, ,,		15,000
Norway		
The Dunderland Iron Ore Co., Briquetting[1]		600,000
England		
E. P. & W. Baldwin, Cromavon, Briquetting		15,000
Spain		
Alquife Mines, Briquetting		60,000
U. S. A.		
Pennsylvania Steel Co., Concentration and Briquetting	100,000	
Berkshire Iron Co., ,, ,, .	150,000	

The report on p. 161 by Messrs Pattinson and Stead[2] on the treatment of Herrang ores by the Grondal dressing and briquetting method, and the behaviour of the briquettes during smelting, is of special interest.

	Fe	S	P
	per cent	per cent	per cent.
Crude ore	39·30	1·13	0·006
Concentrates .	62·90	0·27	0·003
Residues . . .	11·10	1·58	0·017
Briquettes .	61·10	0·008	0·003
Pig iron produced . .		0·005	0·012

The report proceeds "This briquette is excellent in every way. It is hard, porous, and possesses the most desirable properties for treatment in the blast furnace."

[1] In the meantime this plant has been equipped with magnetic ore separators on the Edison dry-concentration principle

[2] *Journ. Iron and Steel Inst.*, 1904, No. I

In the following table the main results of chemical analyses of [illegible]ble ores, concentrates and briquettes from various Gröndal plants [illegible] communicated

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
F[illegible]	S	P	F[illegible]	S	P	[illegible]	F[illegible]	[illegible]	[illegible]	Porosity Vols.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	per cent
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 20
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 20
[illegible]	6 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	67 04	[illegible]	[illegible]	20 9
[illegible]	[illegible]	[illegible] 12	6 95	[illegible] 36	[illegible]	19 [illegible]	66 50	[illegible]	[illegible]	21 3

In the following pages two of the Swedish Gröndal installations, alluded to above are described They are the Flogberget Magnetic Iron Ore Concentration and Briquetting plant at Smedjebacken in the Dalarne province, built in 1905 and the purple ore briquetting works of the Helsingborgs Kopparverks Aktiebolaget which is some years older but has been brought up to date by the installation of modern English presses

II The Flogberget Magnetic Iron Ore Dressing and Briquette Works at Smedjebacken (figs. 61 63, and Plates II and III)

The crude ore is a very dense hard material similar to greenstone in character and contains magnetic iron ore in a finely divided state, its iron content only amounts to 27 to 29 per cent Obtained in a closely situated open working by hand drilling and blasting, it is brought away from the workings in buckets and tipped into wooden

bunkers, from whence it is conveyed to the upper storey of the dressing plant in trough-shaped tipping waggons.

The spacial arrangement of the dressing and briquetting plant can be seen from the plan shown in fig. 61. The works is situated on the slight incline of the quarry so as to utilise the fall of the land. The three level, main buildings of the dressing plant is overlooked by the tower-shaped stone breaker and store house, connected with the top of

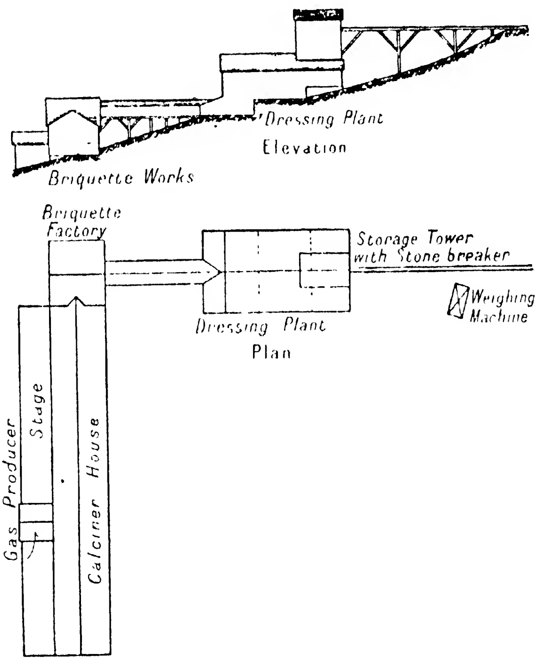


FIG. 61.—Ground plan of the Flogberget magnetic iron ore dressing and briquetting plant.

the bank by a bridge, and is itself connected to the briquetting works by means of a second bridge. The briquette works is made up of the press house and the long furnace house, with the gas-producer house and loading stage.

(a) The Dressing Plant.[1]

The nature of the crude ore necessitates its being ground to the very finest degree. Rich magnetic ore concentrates are obtained from the sand and slimes by magnetic separators and sent to the briquetting plant.

The process of dressing is indicated in Plate II.

The crude ore is first passed through a stone breaker and reduced to lumps of about 8 cm. in size, which fall into a spacious storage bin. From this it is conveyed by feeding rolls, an endless belt conveyor, and a chute to the wet ball mill of the Grondal type situated in the upper storey of the main building. At the same time water is allowed to flow in.

The very simple mills are made up of grate bars and armour plates, are 2 metres in diameter and 2 metres in length, and contain hard steel balls of various sizes up to 145 mm. in diameter and 13 kgs in weight, the total weight being about 1 ton. The mills are half full of water, and revolve at the rate of 28 revolutions per minute. About 2·7 tons of crude ore are worked up per hour, and the wear of the balls is about 1 kg per ton of ore powdered.

Ore charged in is gradually ground finer and finer by the rolling and falling balls until it is fine enough to flow from the centre of the external back wall of the drum with the steady current of sand and slimes.

The slimes flow into two slime separators with sloping sides. Bar magnets are arranged above the settlers so as to influence the surface of the slimes. The dimensions of the tanks and the rate of flow of the slimes and of the rising clear water are so chosen or adjusted that all the fine granules contained in the slimes sink on to the sloping sides and flow out at the bottom, as crude sandy concentrates, through the draw-off pipe of a magnetic separator, while the finest particles rise with the water and are drawn off as waste slimes into a gutter at the front narrow side of the tank. Any fine magnetic particles, however, which may have been carried upwards are retained by the upper magnet when they come into its magnetic field. Ultimately they ball up into small lumps, fall off, and sink through the water to the other concentrates.

The sandy crude concentrates are sent to the No. 5 double magnetic separators of the Gröndal system.

Each separator works with a horizontal electro magnet mounted in strong bearings. Several (about five) pole pieces radiate from the axle towards the bottom and front of the drum in such a manner as to nearly touch its inner surface, and in this way a large magnetic field is produced. The drum consists of alternating lamellæ of soft iron and copper, and is closed at both ends with a wide projecting rim and a disc bored with a number of holes (see fig. 9, p. 92).

Below the drum is a vat divided into a small back and a large front division by a partition which does not quite reach to the bottom. The

slimes flow from above into the rear compartment and rise up the partition, near to the bottom of which a powerful stream of water is introduced. This drives all the granules towards the surface so that they come into close proximity with the drum revolving above. Since the lamellæ of iron are strong magnets while they are in the magnetic field of the pole pieces, they attract all the magnetic material from the slimes. The unmagnetic material flows along with the water over the two side walls of the vat into the outer tank provided with inclined walls. The magnetic ore concentrates, however, cling to the iron lamellæ, and on further rotation of the drum are carried to the limits of the magnetic field, where they are mostly detached by the combined action of gravity and centrifugal force. If any remain adhering to the drum they are washed off by a powerful horizontal jet of water.

The magnetic ore concentrates obtained in this way are caught in a box with inclined sides at the bottom, built at the front, and washed into the back division of the foremost drum settler. Here they are washed again and divided into pure ore concentrates and a middle product consisting partly of magnetic and partly of non-magnetic material. The concentrates are sent to one of the four shaking drainage tanks, and the middle product to a tube mill for further fine grinding.

The tube or flintstone mill is situated below the magnetic separators in the basement of the main building, and in general resembles the German tube mills of Fried. Krupp Grusonwerk, Maschinenbauanstalt Humboldt, and others.

It is 4 metres long, 1·2 metres diameter, is charged with flints from Malmö on the south coast of Sweden, and is driven at 25 revolutions per minute by means of toothed gearing.

The "middlings," whose grain size amount to about $\frac{2}{3}$ mm., are washed with a little water through a down tube opening into the middle of the front wall of the mill, and are crushed and rubbed by the rolling hard flints. When it has attained the necessary fine state of division ($\frac{1}{10}$ mm.) it is carried out with the steady stream of slimes issuing from the other end of the tube mill into the pit of a neighbouring elevator.

This elevator lifts the thick slime to the upper storey of the main building and pours it into a channel leading to a second vat with sloping sides, and provided with bar magnets as before. Again the finest waste particles are carried away by a stream of water and treated as waste, while the coarser particles pass on to a second pair of magnetic separators and are sorted mainly into non-magnetic waste and [illegible]

magnetic iron ore concentrates. The small proportion of "middlings" obtained is passed to the tube mills and treated over again.

The concentrates issuing from each magnetic separator flow to an oscillating iron draining tank (fig 10, p 93).

These shaking boxes are trapezium shaped in section, and, viewed from the side, have the appearance of unequal sided right angled triangles; they are mounted so as to be capable of revolution about the pins on the sides and of vertical displacement, the front being suspended by a chain passing over a hand winch, with a ratchet arrangement mounted close to the ceiling.

When a shaking drainer is full it is lifted by the winch and chain until the upper edges of the side walls and the back edge are in a horizontal plane. Whilst the wet ore concentrates now flow in from above through a funnel, the box is lifted a little and allowed to fall again by means of a cam keyed on to a shaft and acting on an angle iron fastened to the back wall of the box, the action being similar to that in a stamp battery. As a result of these impacts the concentrates settle rapidly and gradually fill the box with a very dense mass, while the water flows over the front edge of the box to a rotary pump. The water rejected is perfectly clear.

The eccentricity of the cam lift amounts to 1 to 2 cm, while the speed of rotation is 36 revolutions per minute. The capacity of the box is about 1 ton of concentrates, the chest being quite filled after about two hours' steady shaking.

When the box is full the front is slightly lowered to allow the clear water on the surface to flow away, after which the box is completely overturned, and its contents discharged into a trough shaped tipping waggon pushed underneath. It usually has to be removed, or the removal assisted, by hand, since the mass is generally very adherent. The tip waggons are then discharged in the stock-room of the briquette factory.

The prepared concentrate is very pure, and is drained to such an extent that it feels just moist on balling up in the hand, and is only moderately plastic. It contains about 8 per cent. moisture and 67·9 per cent. of iron, while the yield is about 37 per cent. of the ore employed. The iron content of the waste material ("afters") amounts to about 6 per cent.

Drive.—With the exception of the stone breaker, which is equipped with a separate motor, the whole of the mechanical appliances (band conveyors, ball mills, tube mills, shaking boxes, rotatory pumps) are driven from a central motor obtaining its electrical energy from the

power station at Ludovika, 10 km. distant. The 10,000 volt alternating current of the mains is previously transformed into direct current of 110 volts.

Water circulation is maintained by a 10 H.P. rotary pump installed in the motor house. The pump lifts the water into a tank in a storage tower, from which it is supplied to the various machines requiring it. Waste water (1100 litres per minute) is replaced by a 30 H.P. pump on the lake at a height of 60 metres.

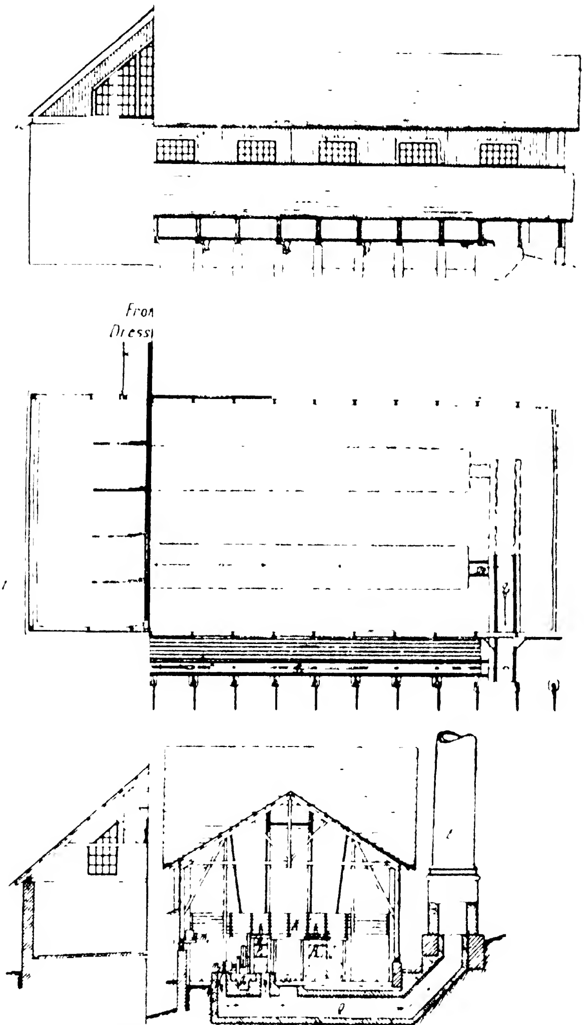
(*b*) **The Briquette Works** (Plate III., and figs. 62 and 63).

Supply and Compression of Ore Concentrates.—The delivery trucks F (Plate III., left), filled with drained magnetic iron ore concentrates, pass over a short connecting bridge to the top storey of the press house, and are emptied into an inclined chute *r*, which causes the ore to slide to the floor of the store A. This is situated behind and immediately above the presses P. Originally there was only one press, P_1, and one channel oven, K_1, in existence, but subsequently a second press, P_2, and channel oven K_2, were installed and put into operation.

In the Gröndal method of briquetting it is only necessary for the presses to produce from the ore concentrates brick-shaped stones, which are just strong enough to be piled on top of one another in waggons and transported to the channel ovens without undergoing fracture For this purpose it is not necessary to add any binding material other than the 8 per cent. of moisture existing in the concentrates.

The briquette press P_1 was supplied by Brefvens Bruk of Kilsmo in 1905. It is constructed exactly on the principle of the Dorsten stone press (figs. 19 and 20, p. 108), is driven by the 6 H.P. motor m_2 (Plate III, left), and works with a hammer-shaped drop stamp weighing 400 kgs., lifted, and allowed to fall three times during each revolution of the driving shaft by a three-lift cam.

The ore concentrates are shovelled by hand from the store A into the charging hopper of the press, fall into a square-shaped mould frame on a slide, and are pushed mechanically over the mould in the press table. At this moment the stamp, lifted by the cam with the short lift, gives a weak blow to the mass and presses it into the mould below. Immediately afterwards the slide moves back, and the stamp, now actuated by the long cams, with a lift of 160 mm, gives the mass two powerful blows, while at the same time the mould frame on the slide is being refilled.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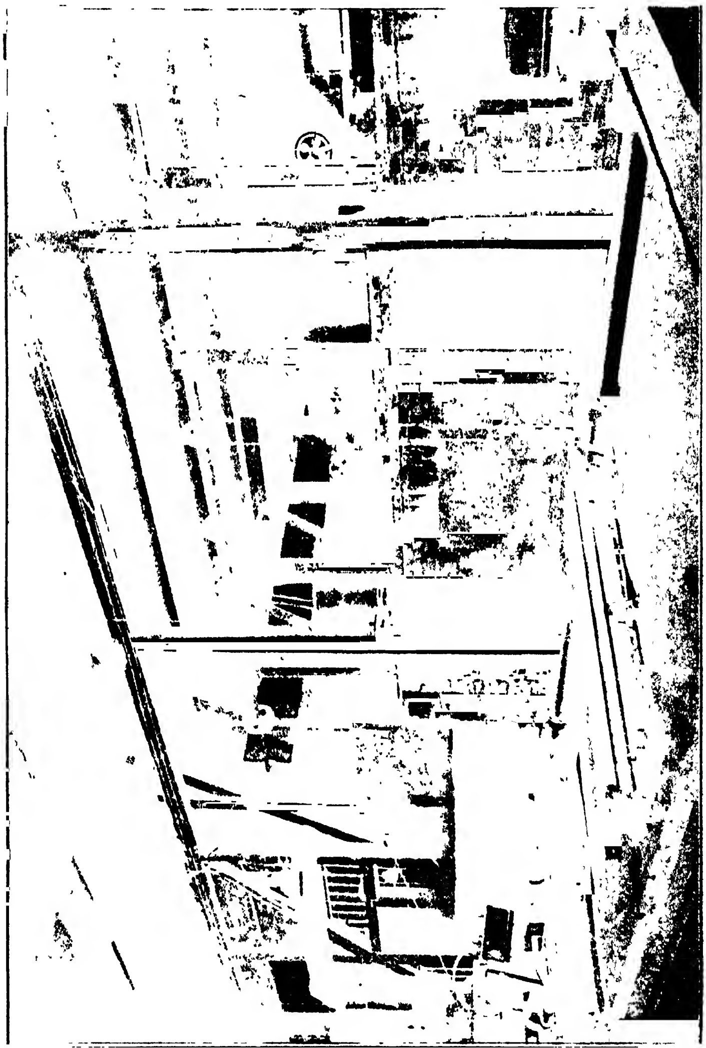
Cross Section III-IV

On the completion of the third blow a lifter in the lower part of the press lifts the block out of the mould to the height of the table

Fig. 62.—Concentrate store and press room with two drop presses for magnetic iron-ore briquettes.

plate, when the slide again moves forward and pushes the raised briquette forward. The cycle of operations is now repeated. Each briquette is removed by hand, as soon as it is pushed forward, by means of a flat shovel, and laid on the waggons standing on the platform moving on the track g_2 close to the presses. The crude

briquettes are in the form of flattened cubes of 150 × 150 × 160 mm in dimensions.



The supply of the concentrates to the presses by hand shovelling is necessary, since, as a result of its moisture content, the mass is too plastic to slide by itself, even though it were conveyed into the charging hoppers of the press mechanically. A ...

just bores a hole in the mass without causing continuous motion of the material. Since the installation of the second press, however, the attendant has been able to look after both

Conveyance of the Crude Briquettes to the Channel Ovens. The briquette waggons, with the low platform for this purpose, are 2 metres long, and generally consist of iron frames filled with refractory bricks, and mounted on two pairs of wheels Their construction and method of loading can be gathered from figs. 62 and 63.

The briquettes are stood flat in inclined parallel series at definite distances from each other on the platform of the waggon. On the first layer laid down in this way a second layer is placed, so that the briquettes of the top layer make an angle with those of the lower layer. The total load amounts to 800 kgs., and the trucks so loaded are pushed one after another from the central track g_2 (Plate III, left), first on to a travelling platform moving on the cross track g_3 They are then pushed on to the track g_1, and thence to the opening of the channel ovens situated at the end of this track (fig 63).

Calcination of the Briquettes in Channel Furnaces. The channel ovens are heated with producer gas, and during continuous working are provided with an uninterrupted series of full briquette waggons. An oven 56 metres in length will accommodate 28 waggons, which are moved forward periodically with the assistance of a Gall's chain situated in the centre of the track below them, and are in time conveyed right through the furnace.

The trucks themselves divide the oven into an upper and a lower channel. One end of the waggon is grooved and the other tongued, so that they can fit together and form a gas-tight joint Both sides of the waggon are provided with wide projections fitting into grooves filled with sand on the right and left walls of the oven The air necessary for the combustion of the producer gas passes underneath the waggon platforms in the direction of their motion, and in this way cools their wheels and frames. It then rises in front of the first waggon, moves in the upper part of the oven towards the combustion space, occupying about two-thirds of the length of the chamber, and becomes heated by contact with the burnt briquettes (see Plates II. and III.).

In the combustion space the stream of air comes into contact with the gas generated from English coal in the bottom blast producer G and led into the oven through a short pipe. During combustion a temperature of 1300 to 1400° C. is produced. The burnt gases meet

the oncoming waggons in the upper part of the chamber, and finally issue through the holes f (sections III.–IV.) into the cross flue Q, to be drawn off by the chimney E. During the passage the gases are cooled down to below 100° C.

Consequently the crude briquettes led into the oven, since they are continually absorbing heat from the gases, get hotter and hotter as they approach the combustion space. Here they are subjected to the highest temperature, and on proceeding farther they give up a portion of their heat to the opposing current of air. They leave the oven at about the same temperature as the exhaust gases reach the chimney, namely, at slightly below 100° C.

The utilisation of heat is therefore very efficient, the main loss being caused by the evaporation of the moisture (about 8 per cent.), still contained in the rough briquettes. When the oven is dealing with iron-ore concentrates and producer gas, as in this case, the coal consumption never exceeds 7·75 per cent. of the weight of the roasted briquettes.

Output of the Oven.—Each waggon remains in the oven for about 19 hours, so that a waggon load of finished briquettes is withdrawn from the oven every 40 minutes. In 24 hours, therefore, 28·8 tons of finished briquettes are produced. (The loss in weight by evaporation of the water content has not been taken into account here; it will, in any case, be partly replaced by absorption of oxygen, owing to oxidation of the heated briquettes (see below).) This output is comparatively small. In the brochure of the Metallurgiska Patent Aktiebolaget, Stockholm, "Enrichissement et briquetage des minerais de fer," the output of a Grondal channel oven is given as 30 to 100 tons in 24 hours. It varies according to the nature of the ore applied and the degree of the desulphurisation effected, but during normal working it can be taken that a waggon load of finished briquettes is removed every half-hour. If such conditions existed at Flogberget, the daily output of an oven would amount to about 38 tons. The object of leaving the briquettes in the oven for a further 10 minutes is to remove by roasting as much as possible of the relatively high sulphur content of the concentrates.

Further Treatment of the Burnt Briquettes.—Each hot waggon drawn from the oven is pushed by means of the travelling platform moving on the track g_5 (Plate III.) on to the wharf track g_6 running along the front side of the oven house. Here it is gripped by a Gall chain carried on the rollers r and removed to any desired storage place

...e chain is driven by the same 10-H.P. motor driving the one inside ...e oven.

There are holes in the wharf track so that the trucks can be cooled ...m below. The briquettes are picked up one by one by means of ...ecial tongs and either thrown or laid on the store situated in front ... the wharf. They may be loaded into railway waggons only when ...ite cold, the operation being effected by hand.

The briquettes are not sold to outside firms, but are sent exclusively ... the somewhat remotely situated small blast furnace plant owned by ...e proprietor of the Flogberget works. They are then smelted with ...harcoal.

Properties of the Finished Ore Briquettes. The finished briquettes ...ow that they have been uniformly and thoroughly calcined without ...aving been fused or slagged. Some are partially free from cracks, ...thers are penetrated by cracks, occasionally the edges and other ...ortions are somewhat broken, the latter faults being often traceable ...o the worn condition of the press stamp and moulds. For transport ...nd application in the blast furnace they have not to fulfil a great ...deal, although cracked briquettes are naturally much more easily ...broken and disintegrated than absolutely dense stones.

With regard to contraction, it is worthy of notice that the burnt ...bricks have somewhat smaller flat sides than the wet briquettes ...(145 × 145 instead of 150 × 150). The thickness, however, is not ...decreased, but has rather increased from 60 mm. to about 80 mm. ...The colour is dark grey with a tinge of reddish ; the streak is dark ...cherry-red. Usually the hardness and strength are high, correspond...ing to the similar properties of good clinker bricks.

In addition to these properties, special mention must be made of ...the porosity of these briquettes. It has been shown by experiment ...that strong, dense Grondal briquettes are capable of absorbing between ...20 and 24 per cent. of their volume of water (see table on p. 161).

The iron content of the calcined Flogberget stones is given as ...60 to 65 per cent. on the average, although it often rises up to ...68 per cent. The magnetic iron-ore concentrates of the crude ...briquettes are probably converted into a higher state of oxidation. ...This is confirmed by the change in colour and streak, and also by ...the fact that the strong magnetic properties of the concentrates and ...the unburned briquettes completely disappear after calcination.

The sulphur content of the finished briquettes never amounts to ...more than a few thousandths per cent.

SUMMARY OF THE POWER REQUIREMENTS, ATTEND REQUIRED, AND THE INSTALLATION AND WOR COSTS OF THE PLANT.[1]

Power Requirements.

A. Dressing Plant.

1 stone breaker		40 H.P.	(special m
1 belt conveyor		1 ,,	Main moto
2 ball mills (each 45 H.P.)		90 ,,	
1 tube mill		40 ,,	
1 elevator		2 ,,	
1 rotatory pump		10 ,,	
4 shaking boxes (each 1 to 2 H.P.)	average total	6 ,,	
	Total	189 H.P.	

B. Briquetting Plant.

1 press	6 H.P.	(special m
2 fans, each of 5 H.P.	10 ,,	,,
2 Gall chains (moved periodically)	10 ,,	,,
Total	26 H.P.	

The total for A and B is 189 + 26 = 215 H.P.

Attendants.

Per shift of 12 hours.	2 men for the stone breaker
	2 men ,, ,, magnetic separators and other dressi
	1 man ,, ,, press supply shop.
	2 men ,, ,, presses and loading briquette waggo
	1 man ,, ,, gas producer.
	2 men unloading finished briquettes.
Total .	10 men per shift or 20 men per day.

In addition there is one works manager and a repair mech making a total of twenty-two men.

The wages of the workmen average 3 kronen (3·36 M.) per shi

[1] The figures given refer only to the original plant with one press an channel oven.

Costs of Installation.

A. *Costs of Installing the Dressing Plant, excluding the Electric Power Plant.*

Foundations and buildings	17,100 kronen.
Stone breaker and mills	31,200 ,,
Magnetic separators and their electric plant	11,320 ,,
Shaking boxes, water and slime pipes	6,200 ,,
Erection of machines	2,480 ,,
Railways and waggons inside the buildings	2,360 ,,
Wages and honorarium for the master builder	3,740 ,,
Total	74,400 kronen 83,328 marks.

B. *Costs of Installing the Briquette Works.*

Briquette press	3,800 kronen.
Oven and chimney	30,400 ,,
Gas producer	3,150 ,,
Waggon	8,600 ,,
Motors and transmission	1,800 ,,
Buildings and sundries	17,480 ,,
Total	65,530 kronen = 73,394 marks.

The total of A and B = 139,930 kronen = 156,722 marks.

To this must be added the costs of installation of the electric power plant, the rotatory pumps and the fans, which should come under A, and have not been taken into account in the above cost sheet. Including these items, the total cost of the dressing and briquetting plant amounts to about 175,000 kronen or 196,000 marks.

Costs of Working.

The total cost of production of a ton of finished briquettes, inclusive of mine costs, sinking fund and interest on the cost of installation (10 per cent.), is given as 14 kronen (= 15·68 M.).

Of this the pure briquetting costs may be put down at 3 kronen (= 3·36 M.).

The Metallurgiska Aktiebolaget give the following detailed estimate of the briquetting costs:—

Briquetting Costs per Ton of Briquettes

(exclusive of sinking fund and interest on capital).

Wages—	Kronen.	
For transport to press	0·32	
" pressing and laying briquettes	0·56	
" gas production	0·09	
		0·97
Power machines		0·09
Coal (7·74 per cent. of the weight of briquettes)		1·30
Repairs—		
To the press—		
Wages	0·04	
Materials	0·03	
		0·07
To the ovens—		
Wages	0·03	
Materials	0·06	
		0·09
To the waggons		
Wages	0·11	
Materials	0·16	
		0·27
Other costs		0·15
Total		2·94 kronen
		=3·30 marks.

The costs of dressing (excluding sinking fund and interest o pital) per ton of crude ore are given as follows.—

Stone breaker—	Kronen.	
Wages	0·05	
Materials (wear)	0·06	
Power [1]	0·10	
		0·21
Ball mills—		
Wages	0·08	
Wear of balls	0·12	
" bars and plates	0·08	
Other materials	0·08	
Power [1]	0·35	
		0·71

[1] The costs of untransformed electrical energy at the motor shaft is ( )·18 M.) per H.P. year.

...mills—

Wages	0·01		
Wear	0·02		
Power[1]	0·07		
		0·10	
[M]agnetic separation—			
Wages	0·05		
Material	0·04		
Power[1]	0·03		
		0·12	
[W]ater consumption		0·11	
[T]ransport and sundry operations inside the works		0·18	
[S]uperintendence and sundries		0·09	
Total		1·52 kronen	1·7[illegible]

[S]ince, as pointed out above, the yield of concentrates amounts [...] per cent. of the crude ore treated, the costs of dressing per to[n] [of conce]ntrates amount to —

$$\frac{1\cdot52 \times 100}{37} = 4\cdot11 \text{ kronen or } 4\cdot60 \text{ marks.}$$

[N]ow 1 ton concentrates give approximately, though somewhat less [tha]n, 1 ton of briquettes, so that the sum of 4·11 kronen can be taken [as a]pproximately applying to 1 ton of briquettes.

At an estimate of 10 per cent. the amount deduced for the sinking [fun]d and interest on the capital cost of the complete dressing and [bri]quetting plant (175,000 kronen) is 17 500 kronen per annum, which, [wit]h a daily output of about 29 tons of briquettes for 300 days of the [yea]r, works out at $\frac{17500}{29 \times 300}$ = about 2 kronen or 2·24 marks per ton [of] briquettes.

The mine costs at the works are given as 2 kronen (= 2·24 marks) [per] ton of crude ore, with the possibility of a reduction to 1 krone [(=]1·12 marks) after the introduction of a boring machine. With a [37]per cent. yield of concentrates, the mine costs per ton of concentrates [wor]k out at $\frac{2 \times 100}{37}$ = 5·40 kronen (= 6·05 marks).

Summing up, the total working costs per ton of briquettes are as

---

[1] See footnote on p. 174.

Mining costs	5·40 kronen.
Dressing costs	4·11 „
Briquetting costs	2·94 „
Sinking fund and interest	2·00 „
Total	14·45 kronen (=16·19 M.),

a total which is in good agreement with the approximate figure of 14 kronen per ton of briquettes given by the works.

The proprietor assumes for the purposes of calculation that the value of the briquettes charged into his blast furnaces is 17 kronen per ton.

For comparison, some figures obtained by A. Johannsson[1] at the Sandviken briquette works, erected in 1905, are given here.

III. Sandviken Magnetic Iron Ore Briquette Works.

The channel oven is 52·5 metres in length, and is heated by means of blast furnace and producer gas. The coal consumed per ton of briquettes amounts to 5·64 per cent., of which 1·36 per cent. is assigned to the blast-furnace gas. 16 to 18 waggon loads (each of about 830 kgs.) of briquettes are obtained per shift, giving a weekly output of 190 to 210 tons.

The briquetting costs, exclusive of sinking fund and interest, amounted, in 1907, to:—

Direct working costs	2·59 kronen.
For repairs	0·39 „
Total	2·98 kronen (=3·34 M.),

which are almost exactly the same as the Flogberget costs.

IV. Purple-Ore Briquette Factory of the "Helsingborgs Kopparverks A.-B." at Helsingborg (Sweden).[2]

The briquette works forms a portion of the large copper-extraction plant of the above company at Helsingborg on the west coast of South Sweden. In this plant the export pyrites, obtained and dressed at the Sulitjelma pyrites mines in North Norway and transported in the company's own pyrites boats, receives its final treatment after it has first given up the greater part of its sulphur content during roasting for the production of sulphur dioxide in the paper factories on the south coast of Norway.

[1] *Jernkontorets Annalen*, 1908, Nos. 5 and 6, p. 400 and p. 434.

The burnt pyrites constituting the residue are again loaded into coasting steamers and transported to the Helsingborg copper works. Here endeavours are first made to recover the silver and copper contents as completely as possible

With this object the residue is roasted with ground common salt in tall shelf furnaces with continuous rabbles for the purpose of chlorination. The material is then lixiviated with water and the silver precipitated with potassium iodide (Claudet's process), while the copper is subsequently precipitated as "cement" by means of metallic iron. The cement copper contains about 80 per cent Cu, and is melted in double reverberatory furnaces to refined copper of 99·97 per cent. purity. About 2000 tons of this material are produced every year.

The powdery residue from the copper lixiviation is called purple ore, and consists principally of oxide of iron. It is stored in sheds in order to become air-dried, but in the prevailing moist climate still retains 18 per cent. of moisture. It usually contains 61 per cent. Fe, 0·15 to 0·20 per cent. Cu, 0·23 per cent. S, and 0·01 per cent P.

The main equipment of the briquetting works consists of three Sutcliffe presses, three older drop presses (now only acting as reserves), three Grondal double reverberatory furnaces, with two Bild producers, which stand in the open at the side of the furnace house and are jacketed with tarred sheet-iron covers

The construction, etc, of the Sutcliffe presses are described on p. 122 *et seq.*, and illustrated by figs 30 to 38, while they are compared with drop presses on p. 129. At Helsingborg the output of a Sutcliffe press per minute is 24 briquettes, each weighing 4 kgs, equal to 1440 briquettes per hour, or about 13,000 -52,000 kgs. per day of nine working hours. Each press requires the attention of one man for feeding and four men for the removal of briquettes from the mould table for their piling on briquette trucks and removal to the oven.

The period of burning lasts about nine hours The finished briquettes have sharp edges, are free from cracks, and are dense and strong, but very porous (see fig. 4 (2)), their iron content amounts on the average to 62 to 63 per cent., with 0·19 per cent. Cu, 0·06 per cent. S, and 0·01 per cent. P.

Comparing this composition with that of the purple ore previous to briquetting, it will be noticed that the iron content has been increased by 1 to 2 per cent., the sulphur content has been diminished by 0·2 per cent., while the contents of copper and phosphorus remain about the same.

The quantity of briquettes passing through each oven per day about 75 tons, giving a total daily output of approximately 225 to or a monthly output of 6750 to 7000 tons of briquettes when the ove are kept in continuous work.

The staff of the briquette works consists of twenty-three men d tributed over three eight-hour shifts, and in receipt of an average wa of 4·25 kronen (4·76 marks).

The coal consumption amounts to 8 or 9 per cent. of the brique production, consequently to $\frac{225 \times 85}{100} = 9{\cdot}12$ tons per day, all of which obtained from England. In 1906, 1 ton of coal cost 15 kronen (1 marks). With a daily production of $3 \times 75 = 225$ tons, 1 ton briquettes has assigned to it the following costs:—

$$\text{In wages} \quad \frac{23 \times 4{\cdot}76}{225} = 0{\cdot}49 \text{ marks.}$$

$$\text{In coal} \quad \frac{19{\cdot}12 \times 16{\cdot}80}{225} = 1{\cdot}43 \text{ marks.}$$

No further information as to costs have been obtained. The sale briquettes is limited to England, and in 1906 the selling price was 2 (=22·44 M.), and the freightage 5s. (5·10 M.) per ton.

V. Iron-Ore Briquette Factory at the Alquife Mines and Railwa Co. Ltd., in the Province of Granada, Spain.

The complete plant was built in 1908 by Messrs Sutcliffe, Speakm & Co. Ltd., of Leigh, England, and is equipped with three Sutcli presses and six Grondal ovens for a daily output of 150 tons.

It consists of four main parts:—

1. Sieving plant with loading of coarse ore,
2. Mixing and compression plant,
3. Channel oven plant, and
4. Briquette loading plant.

Sieving and Loading Coarse Ore.—The ore, obtained from op workings, is for the most part fine or dusty, is usually dry, and requi no further treatment beyond sieving for the removal of the coarse o This is effected in a sieving plant capable of working up 300 tons a day of ten hours. It is equipped with automatic, piano-wire sie which hold back anything larger than 7 mm. This coarse mat taken up by two rising band conveyors and carried to iron bi

The ore is conveyed to a storage bin of 500 tons capacity by means of an elevator. From this bin it is carried to the press house by a second elevator. The band conveyor and elevators are driven by a 15 H.P. motor.

The Mixing and Compression Plant has an output capacity of 180 tons in ten hours. A worm conveyor arranged above distributes the fine ore into three differential mixers provided with double shafts. where it is moistened if necessary and thoroughly mixed up. From the mixers the ore slides down inclined chutes to the feeding pans of three simple Sutcliffe Emperor presses.

The freshly pressed blocks (254 × 127 mm.) are laid by hand on to briquette waggons for the channel ovens.

Any excess in the delivery worms falls at the end on to a band which conveys the material to a second worm conveyor This transfers it to the first elevator, whence the material passes through the plant again.

Two electric motors, each of 100 H.P., drive the conveyors, mixing, and press appliances. Only one is in use at a time, the other being kept as reserve.

The channel oven plant consists of six Grondal double reverberatory furnaces with two gas producers. Each oven has a daily output of 25 tons of briquettes.

Loading the briquettes on rail is effected by a rising band conveyor and a chute.

Like the coarse ore, the briquettes are railed to the coast and shipped to England.

The electrical energy necessary to drive the motors is obtained from a distant water-power plant.

A similar plant is in the course of erection for the Compania Minera de Sierra Menera in Spain by Messrs Sutcliffe, Speakman & Co. It is intended to install seven Emperor presses at this plant.

SECTION VII.

COMPLETE AGGLOMERATION PLANTS.

FELLNER & ZIEGLER SYSTEM OF REVOLVING TUBE FURNACE AGGLOMERATION PLANTS (figs. 64 to 76).

'HE few revolving tube furnaces existing in Europe for the agglome ion of ores, etc., have for the most part originated from Fellner Ziegler of Frankfurt a. M.

This renowned firm has made a speciality of the construction of revol ubular furnaces and other plant for the manufacture of cement for sev ears, and has made great progress in the construction and perfection of iethod of calcining. In addition to their factory at Bockenheim, they pos large experimental station with laboratory.

The method is carried out in furnaces similar to those used ement manufacture, and generally the firing is effected by mean oal dust or producer gas.

The normal arrangement of a complete agglomeration plant on principle, with two tube ovens and coolers, coal driers, coal mills, other accessories, is shown in figs. 64 to 66, while special details llustrated in figs. 67 to 76.

Agglomeration Furnace.—The finely ground material is supp continuously to the upper end of the tube furnace, consisting very long drum made of wrought-iron plates lined with refract bricks. It is inclined at 6 : 100 to the horizontal, and slowly revo on pairs of rollers. As a result of the rotation the material gradu rolls and slides through the whole drum towards the lower end, com into contact with a counter-stream of hot gases, which gradually r its temperature, dry and calcine it. The hot gases are produced blowing finely ground coal dust or producer gas with the requ quantity of air through the opening in the lower end of the drum means of a jet fixed in a steep upward direction on the pipe

place, and the point where the flame strikes the material is most strongly heated, resulting in the latter becoming white hot and plastic.

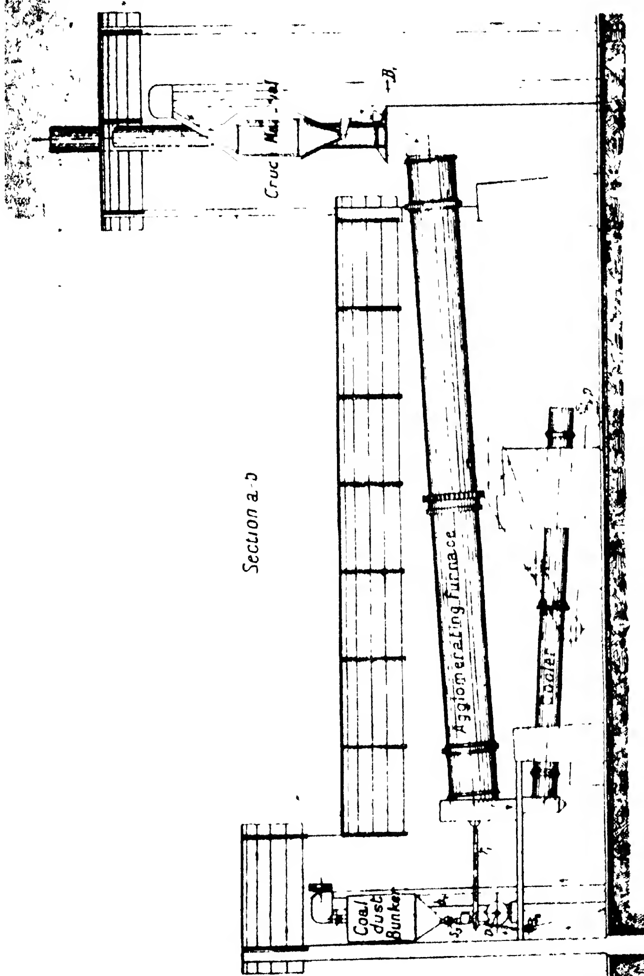


Fig. 64 —Revolving tubular furnace by Fellner & Ziegler

From this point to the lower end of the oven the temperature falls rapidly, and the soft material balls up to egg- or ball-shaped lumps in this region. These lumps roll from the lower end of the drum in a red-hot state, and to the upper end of a lower drum known as the cooling drum. The cooling drum (cooler) is similar to, but narrower and consider-

ably shorter than the calcining drum. It has, however, the sa
inclination, but in the opposite direction. By its slow rotation

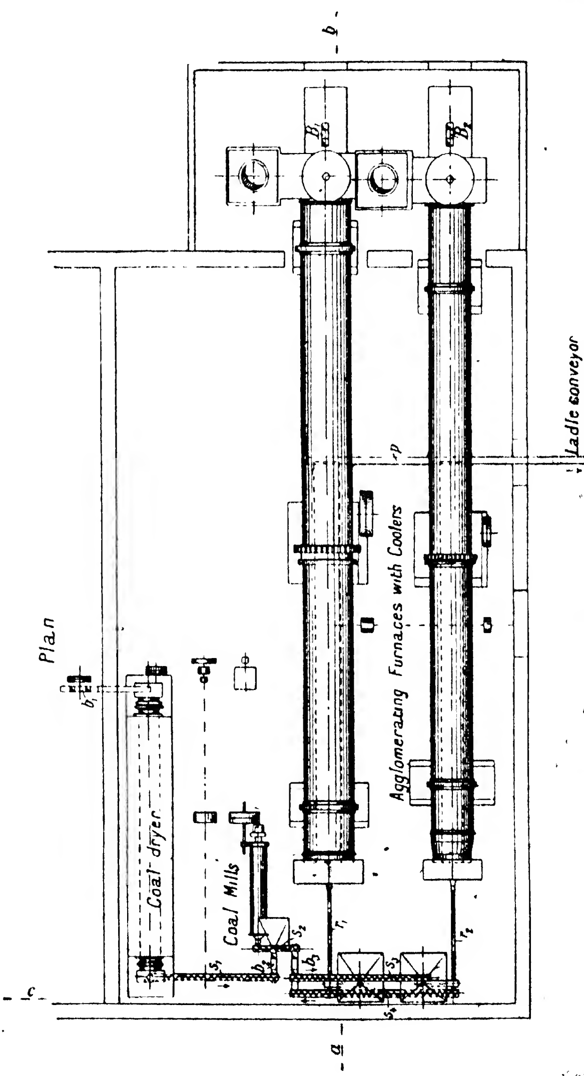


FIG. 65.—Revolving tube furnace agglomerator. Fellner & Ziegler.

gradually conveys the material through it and discharges at its lo
end. The material is cooled to 50 to 60° C. by the current of air
ing through the open drum, and can be conveyed direct to the

A cooling drum is not absolutely necessary. At the Giessener Braunsteinbergwerke the agglomerate discharged from the lower end of the tube furnace is first allowed to heap up in an open storage bin and cooled by the surrounding air before being taken away in iron tipping waggons and emptied into railway trucks, where it is drenched with water.

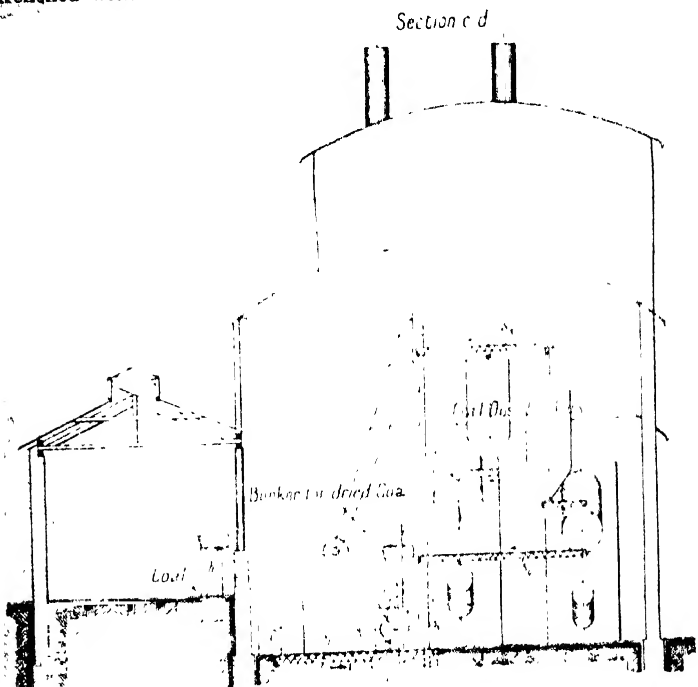


Fig. 66.—Revolving tubular furnace agglomeration plant by Fellner & Ziegler. Cross section.

The chief difficulties of agglomeration in tubular furnaces consist in so arranging and working the plant that the material only softens in the flame and does not fuse either wholly or superficially. This would hinder the penetration by reducing gases in the blast furnace (see p. 14). Therefore continual care must be taken to maintain the correct conditions in the flame, determined by experiment on the material under treatment at the time.

With the aid of the arrangements described below, it has been possible to master all the difficulties at the works, where the method has been applied for some time, and to obtain by careful working

perfect, hard, and porous (unfused) agglomerate. Neverthele[ss] it is impossible to completely prevent the formation of a layer [of] fused material on the oven lining in the hottest or agglomerati[ng] zone, and it becomes necessary, after continually running the furna[ce] for periods up to ten days and nights, to stop the working a[nd] remove the obstructions which diminish the sectional area of t[he] tube. The furnace is then ready to be used for another simil[ar] period.

The principal dimensions, etc., of the various agglomeration a[nd] cooling drums which have been built or proposed up to the prese[nt] time are given in the following table:—

Kind of Drum.		Dia.	Length	Thickness of Wall of the Wrought-iron Jacket.	Thickness of Wall of the Firebrick Lining.	Inclination of Drum.	Revolutions per min.	Power Consumption.	Output per hr.	Output pe[r] 24
	No	metres.	metres	mm.	mm	per cent.		H.P.	tons.	t[ons.]
Calcining drum	1	1·6	30	20	20–25	6		.	3·3–3·8	8[0]
or	2	2	30–35		exceptionally		1	5	6	1
agglomerating	3	3·4	45		ally 40		to	to	to	
furnaces.	4	3	60		Trzynietz.		½	15	6·7	1
Cooling drum	1	1·4	17	20	20–25	6				
	2	2	20		(40)		...	..	...	

The mantle of the drum consists of lengths of iron tubes, each metres long, bound together by means of iron bands.

Advantages of Large Drums.—The smallest calcination and coolin[g] drums (No. 1 of the above table) have only been supplied to the ver[y] first installation on the Continent for the agglomeration of iron ore and similar products, built in 1905, at the ironworks at Trzynietz, nea[r] Teschen (Austrian Silesia). In spite of numerous stoppages under th[e] prevailing conditions, they worked so well that in 1908 a second calcina[-]tion drum with cooler and accessories was installed. With a lengt[h] equal to that of the first, the second drum had a diameter of 2 metre[s]. Considerable advantages were noticed during its use: the outpu[t] was almost doubled, as will be seen from the last column, and, furthe[r,] the working period was increased from five (in the case of the 1[·6] metres drum) to ten days before it became necessary to dress the lining. This means an increased life of the furnace.

The increase in the output needs no further explanation.

The extension of the working period is explained by the fact th[at] the formation of internal fused deposits does not have such a

obstructing effect in the drum of larger area of section. Again, the walls of the lining are farther away from the jet of flame, and can, therefore, undergo more cooling during rotation. As a result, the fusion of the material is not favoured to the same extent as in the narrower drum, whose lining remains at a white heat continuously.

This factor is of equal importance in the increased life of the lining, which is also contributed to by the fact that the periods in which work is stopped and the furnace cooled down for the removal of obstructions are much less numerous. It is impossible to avoid damage to the lining during these operations.

As a result of these experiences, later agglomeration furnaces have been further increased in diameter, and in the most recent plants the length has also been added to. The largest drums (No. 4 in the above table), of 3 metres in diameter and 60 metres in length, are at present only built for, and have only been tested in, the cement industry. Fellner & Ziegler, however, maintain that they are equally suitable for the agglomeration of ores, and already intend to install them in a new plant to be erected in England.

The weight of one of the largest tube ovens of this description, including the material to be calcined (assuming it to be cement) is about 300,000 kgs. In the working up of ores and similar products the weight would be correspondingly greater.

The lining consists of very refractory material, and preferably of firebrick. It is recommended that an additional thin coating of the material to be treated be fritted to the inner wall of the lining.

Mounting and Drive.—At each end and in the middle the drums are fitted with strong steel bands each mounted on two pairs of rollers (omitted in figs. 64–66), otherwise they are left quite open. The rolls rest on brick pillars, and can be adjusted by means of screw spindles, thus providing a means of compensation for the downward motion of the drum during rotation, and of moving the drum upwards when occasion arises.

For safety and control a round thick friction disc is mounted parallel to the inclination of the drum below the lower pair of rolls of the central support. The disc is mounted so as to be capable of revolution on a strong pin at right angles to the axis of the drum and fixed at a certain definite distance from the central band in such a way that the latter is almost in contact with the edge of the disc. On the slightest downward motion of the drum the two come into contact and the disc is caused to revolve. As soon as this is observed adjust-

ment is made by means of the screw spindles. The friction disc a its pivot can only withstand low pressures, which if allowed to increa will quickly shear off the pivot.

On each drum a spur-wheel is mounted near to the central ste band, and is driven from a common motor by means of a pinion ar bevel gearing.

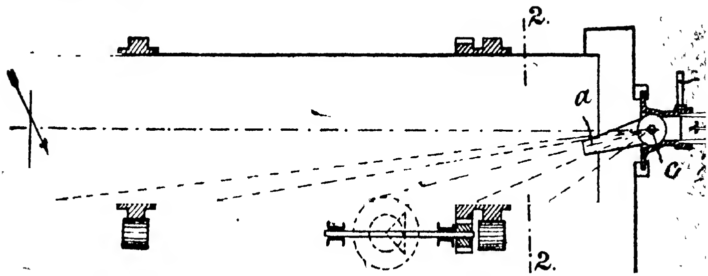


FIG. 67.—Diagrammatic longitudinal section of a drum calciner with revolving nozzle.

The supply of raw material is suitably provided by means of a iron storage bin arranged above the inlet end of the drum calciné The bin (fig. 64) is cylindrical in its central part, and a dust-tigl connection is made with the lip of the elevator B_1 or B_2 by means a conical head and a down tube. At the bottom it is hopper shape and the accumulated raw material is supplied in a con tinuous uniform stream through a bent downcomer t a small supply hopper and inlet chute.

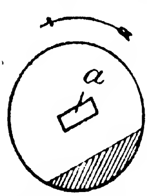


FIG. 68.—Sketch of section through drum calciner and nozzle.

Coal Dust Firing.—A revolving nozzle *a* (figs. 66 71)—Fellner & Ziegler's Patent (D.R.P. No. 154,02 Class 80*c*)—is used for blowing the mixture of co dust and air through the lower opening of the drum This invention, first designed especially for the cemer industry, takes into consideration the fact that th material does not occupy the lowest position in the drum during rota tion, but its surface is inclined as represented in fig. 68.

The angle of inclination depends upon the velocity of rotation and t nature of the material.

Consequently the jet of flame is not directed, as formerly, towar the bottom in a vertical plane, but is rather projected so as to lie in plane at right angles to the surface of the material to be calcined.

If the opening of the nozzle be made flat, the resulting flat sheet of fla

wise to any part of the material which it is desired to heat to a very high temperature, by means of the rotation appliances to be described below. In this way a longer heating zone can be obtained, and the damage caused by impingement of the flame on either side of the material can be effectively prevented.

The angle of inclination of the jet of flame can be varied with the conditions, and its section can also be varied by the choice of a suitable nozzle.

One design is illustrated in figs. 67 to 71. Fig. 67 represents a longitudinal section through a drum calciner, fig. 68 a section on the line 2–2 through the drum, fig. 69 shows a plan, figs. 70 and 71 represent vertical and cross sections through the nozzle appliance, figs. 72 and 73 show a plan (partly in section) and a cross section through a form of nozzle with variable opening.

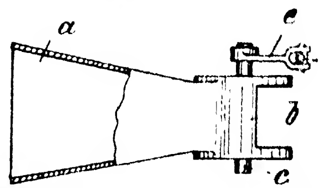


FIG. 69.—Arrangement of nozzle. Plan and section.

a is the mouthpiece whose cylindrical portion *d* can be revolved

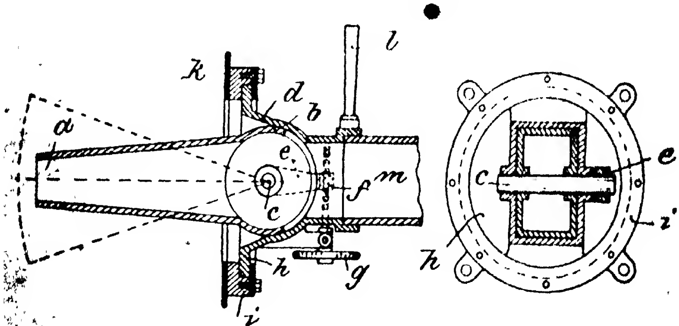


Fig. 70. Fig 71.

FIGS. 70 and 71.—Arrangement of nozzle. Vertical and cross sections.

by the spindle *e* mounted in the housing *d*. Mounted externally on the spindle *c* is the lever *e*, whose link piece *f* is drilled and tapped to take the screw spindle of the hand-wheel *g*.

By means of this arrangement the mouthpiece of the nozzle can be adjusted to any desired angle in the housing *d*. This is made up of a circular plate *h*, fitting into the ring *i*, firmly fixed to the fire plate *k*. The plate *h* has a certain amount of play in the ring *i*, and the fuel supply tube is coupled to the housing *d* in such a way that

the latter can be rotated through a complete circle by means of the handle l or some other suitable arrangement.

In figs. 72 and 73, p are wings capable of revolution about the pivots and of side adjustment by means of the two screws r and s.

The results of using rotating nozzles is the best that can be conceived. At the commencement of a new period of working the nozzle

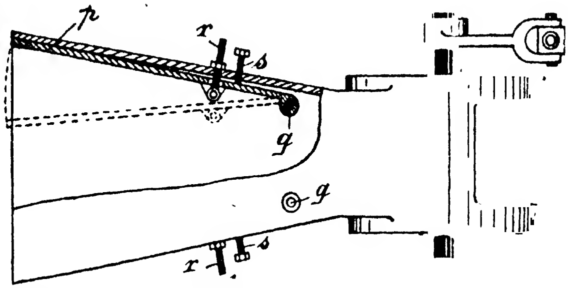


FIG. 72.—Arrangement of nozzle with variable opening. Plan and section.

is adjusted so that the flame plays at right angles to the inclined surface of the material at a point about 5 metres from the front end of the drum. As the formation of fused deposits in the hottest zone increases on further working, the nozzle is adjusted to a more and more horizontal position, and the flame directed on to the fresh material behind the ring-shaped fused mass.

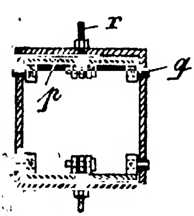


FIG. 73.—Arrangement of nozzle with variable opening. Section

The conditions for the production and uniform maintenance of the necessary high temperature in the flame (1200–1400° C. according to the nature of the material to be calcined) are: application of a suitable kind of coal in the form of a meal of uniform composition and uniformity of fineness (or a suitable gaseous fuel) and its injection in uniform quantity in admixture with the correct proportion of air.

The most suitable coal is one of the easily ignited, long-flaming variety containing little ash, such as, for example, the flaming gas coals from Westphalian seams. Anthracites and similar very hard pit coals and cokes are much less suitable. However, in view of the very high fuel consumption (see below), which is in agreement with the high working costs, it is not always possible to choose the most suitable kinds of coal, but, under certain conditions, much less suitable

For example, at the Trzynietz agglomeration plant mentioned above a mixture of 60 per cent. coke dust (from the waste products of the works' coke ovens, otherwise of scarcely any value) and 40 per cent. coal dust (from the gassy fine coals of the not very remote Karwin coal pit belonging to the same company) are used for firing.

A high content of ash is a disadvantage, inasmuch as it not only decreases the calorific power of the fuel, but at the same time promotes the formation and growth of the fused deposits, this action increasing with the size of the particles.

Partly on this account, but mainly to promote ease of ignition and complete combustion of the fuel in a small space, it is first necessary to grind the coal to the finest possible state of division.

Preparation, Size, and Injection of the Coal Dust or Mixture of Coal and Coke Dusts.--The coal and possible coke smalls must be ground until the whole of the particles will pass through a sieve of $70 \times 70 = 4900$ mesh per sq. cm. It must therefore be well dried previously.

The hot ovens and drum dryers of Petry & Hecking of Dortmund; those of the Zeitzer Eisengiesserei, described on p. 80 *et seq* of Vol. I.; the drum driers of Moller & Pfeifer and of Fellner & Ziegler, etc., described above, are admirably adapted for the drying of moist coal and coke smalls.

In the agglomeration plant illustrated in figs. 64 to 66, a Fellner & Ziegler drum drier of 1 metre in diameter is installed. It is charged with wet coal from an elevator b_1 and an inclined sheet-iron chute. Below the completely bricked drum a coal fire is built, the hot gases of which play on the outside and are then drawn through the drum to the chimney.

From the drum the coal is conveyed to a charging hopper (figs. 64 to 66) by means of a worm conveyor s_1 and elevator b_2, and thence to the double coal mills. These consist of two horizontal drums situated one above the other. The coal charged at the left end is worked up in the upper drum by steel balls 4 cm. diameter, and the coarse meal is transferred to the right-hand end of the lower drum, ground to the finest possible state of division by scrap iron, and discharged at the bottom of the left-hand side (fig. 65).

At the Giessen brown-iron ore mines agglomeration plant, Westphalian small flaming gas coals (maximum size 6–7 mm.) are finely ground by means of oscillating roll mills running at 140 to 200 revolutions per minute. This method of working is very effective, but the dust developed is very troublesome. In addition, the very fine sieves are apt to be damaged by wood

chips or other foreign bodies, and as soon as holes or slits are formed in the sieve a product of irregular fineness results.

A short worm conveys the dust to a third (topmost) elevator b_3, which shoots the fuel into the upper or distributing worm s_3 for the purposes of conveyance and distribution to the two coal-dust charging hoppers of the two tube furnaces. Short worm conveyors, one under each funnel-shaped mouth of the hoppers, convey the dust to a peculiar shaped supply appliance patented by Fellner & Ziegler, which only takes up a certain definite, but adjustable, quantity of dust at a time and supplies it to the corresponding blast pipe r_1 or r_2 of a fan arranged below. Excess of dust falls into an inclined down tube (fig. 65). From this it passes, as shown by the arrows, to a common worm collector s_4, down another downcomer into the pit of the large elevator, and is again lifted into the coal-dust storage bins.

The Fellner & Ziegler patent supply arrangement[1] for taking up and delivering uniform quantities of powdered materials like cement meal, coal dust, and the like is illustrated (in the design which has, up to the present given the best results) by figs. 74 to 76. In the housing a the meal (coal dust in this particular instance) is supplied by the charging hopper b to the guiding piece c, from which it falls on to the well-wheel d. This wheel is rotated at a uniform speed in the direction of the arrow, and as a result delivers the powder taken up into the channel f on the left-hand side of the partition e of the casing a. Excess of material falls to the right into the channel g. In order to regulate the supply the well-wheel is partly surrounded by a revolving slide k which can be rotated about the spindle m, and adjusted by means of an arm n and the screw p so as to vary the distance between the front edge s of the well wheel cover and the edge t of the projection from the top of the casing. Thus the inlet opening into the individual cells of the well-wheel can be varied to any desired amount, and the quantity of material supplied can be regulated.

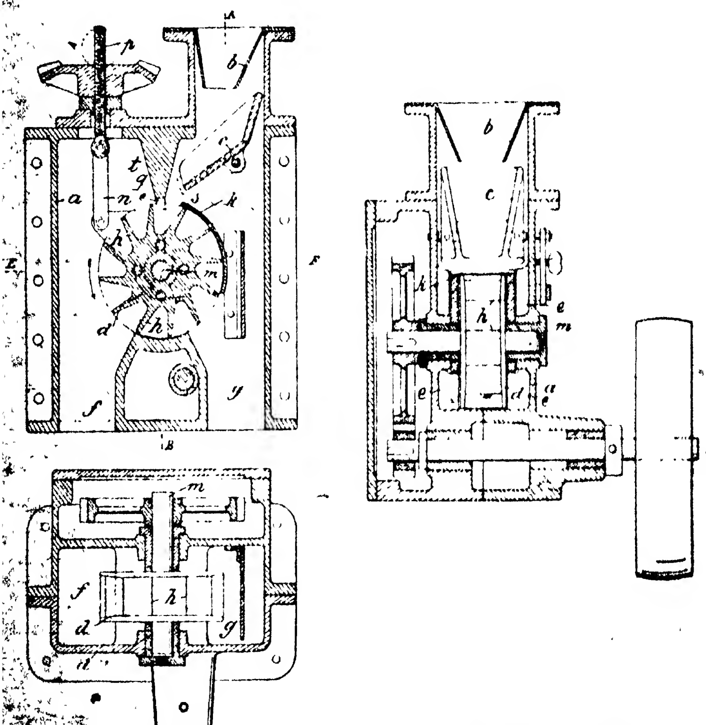
The small beater fan installed in front of each tube oven sucks the air necessary for combustion along its shaft and blows it through a pipe connected to the top of its casing. Here the air is mixed with coal dust introduced as described above, and blown into the nozzle of the tube furnace. The supply of air is regulated by altering the speed of the fan.

In Trzynietz the air supply is not obtained from a fan, but is taken from the blast main by means of a pipe and mixed with coal and coke dust in the ordinary way.

Observation of the jet of flame and the operations in the drum is made through an opening 10 cm. wide in the front wall of an iron box built in front of the furnace (fig. 65).

The coal consumption for dust firing has been found by experience to be about 14 to 16 per cent. of the yield of product.

At the commencement of agglomeration operations at the Giessen works experiments were made in the application of producer gas, but many difficulties were experienced, and coal-dust firing was finally adopted, and is still in use. In principle, however, a method of gas



FIGS. 74, 75, and 76.—Fellner & Ziegler's patent supply arrangement for coal dust.

firing, such as, for example, is invariably used in the Gröndal channel oven, appears to be considerably better, and it is to be hoped that renewed experiments will be made in this direction.

The formation of fused masses, already dealt with on p. 184, takes place at a distance of about 5 metres from the front end of the drum, and as a result of the rotation forms a complete circle round the drum lining. This is naturally thickest in the hottest zone (4 to 5 metres from the front end) and tapers off towards the ends.

The rate of growth of the fused deposit, the length of the working

periods, and the output depend to some extent upon the size of th drum, the nature, ash content, and degree of fineness of the injecte coal dust, and also upon the temperature of the flame, but mainly upo the special properties of the material to be worked up. With regar to the treatment of Giessen manganese ores and fine spathic iron or from Neunkirchen (Siegerland), in the same agglomeration plant the Giessen brown-iron ore mines, the following remarkable differenc have been obtained :—

	Giessen Manganese Ores.	Neunkirchen Fine Spathic Iron Ore.
Calcination period	about 3 days	about 3 days
Period for cleaning out deposits . .	,, 1 day	,, 3–4 ,,
Total time of one run . . .	,, 4 days	,, 6–7 ,,
Monthly output of agglomerate . .	,, 3000 tons	scarcely 1500 tons

Although the Neunkirchen spathic iron ore generally agglomerat better than the Giessen ore—*i.e.* it gives coarser ball- or egg-shap agglomerates—the fused deposits are more extensive, denser, a tougher, so that more care and time is required for their remov This is probably due to the greater content of such impurities pyrites, zinc-blende, and quartz.

The agglomeration plant at Trzynietz appears to give much mo favourable results than that at Giessen. Here a mixture of about per cent. magnetically concentrated Hungarian spathic ore, about per cent. flue dust, and about 65 per cent. burnt pyrites, with sm quantities of manganese, is worked up, and the tube oven of 1·6 met diameter has a working run of 5 days, and the tube oven of 2 met diameter has a working run of 10 days. The subsequent cleaning tal only half a day.

Generally speaking, the following runs can be reckoned on for n installations equipped with tube furnaces of 3 metres diameter: 7 da for the calcination run, 1 day for cleaning, giving a total of 8 days the complete operation.

Cleaning.—Attempts have often been made to remove fu deposits during the working period by means of long iron b provided with sharp, knife-shaped ends of steel. These are introdu through the observation hole and worked about by hand. The rest however, are never very promising. Consequently this method is o adopted when it becomes necessary to remove or equalise cert

ing is carried on after stopping the supply of heat and the rotation of the drum, and removing the fore-box and the nozzle. The deposits are then broken loose by means of iron bars, wedges, and heavy hammers, removed and kept apart from the heap of agglomerate.

When the mass is very tough this work is exceedingly tedious, and it is advisable to seek a more convenient and rapid method of removing the deposits, probably with the aid of pneumatic hammers or the oxyhydrogen flame.

Wear and tear of calcining drums in the agglomeration zone is brought about partly as a result of high temperatures, and largely by the fracture of the lining during removal of the fused masses. As a result, the last two sections of the drum (each 3 metres long) must be renewed after about 6 months' working. This causes a stoppage of 1–2 days. The remaining and largest portion of the drum stands up very well.

In Trzynietz, this renewal is only necessary about every seven months. Otherwise, even in the older drum, which has been in operation since 1905, no other delays have been experienced, and the operations have never been suspended for a longer period.

The chemical and physical changes in the tube furnace agglomeration plant depend, in the first place, on the nature of the material supplied, further, on the diameter, length, and speed of rotation of the drum, and also on the temperature and direction of the jet of flame.

The material is completely dried by the opposing current of hot gases; most of the water of hydration is expelled, carbon dioxide is driven out of the carbonates, and the sulphur from pyrites zinc-blende, copper pyrites, and the iron sulphate existing in burnt pyrites is evolved as SO_2. In addition, many other chemical changes, such as oxidation, etc., take place.

EXAMPLES.

I. Agglomeration Plant at Trzynietz.

The equipment of this plant, which has already been mentioned several times, resembles, on the whole, a normal installation of the Fellner & Ziegler system, except in the different diameters of the two tube furnaces. Usually a mixture of 14 per cent. fine roasted spathic iron ore, about 21 per cent. flue dust, 65 per cent. burnt pyrites, and some manganese ore slimes are worked up.

The fine roasted spar is obtained by crushing and magnetically

concentrating (up to 45 per cent. Fe) the waste lumps picked out duri
the roasting of spathic iron ore at the company's Hungarian min
This material was formerly thrown on to the tip. The burnt pyri
contain 50–60 per cent. Fe and about 2·5 per cent. S, together wi
small quantities of P, Cu, Pb, Zn, Co, and Ni.

Flue dust from the blast furnaces contains about 40 per cent.
and the manganese slimes about 25 per cent. Mn and 20 per cent
Addition of the latter appears to be advisable on account of the l
manganese content of the other ingredients.

In the agglomeration of this mixture in two tube furnaces fi
by a mixture of 60 per cent coke dust and 40 per cent. coal dust t
following advantages have been obtained :—

1. The application of fine-grained dusty iron ores in unlimited qu
tities has been rendered possible, and the local shortage of lump c
completely overcome.

2. The coke breeze, formerly regarded as a troublesome waste p
duct, and the scarcely marketable coal dust, have been turned to use
account.

3. An increase in the iron content, amounting to about 20 per ce
has been brought about by the evolution of moisture and sulp
dioxide, together with some oxygen, carbon dioxide, etc. The ag
merates contain on an average 56 per cent. of iron.

4. The content of S is reduced from 1 to 0·2 per cent. down to tra

5. A more regular working of the blast furnaces has been obtain
as made evident by an increased output, considerably lower consu
tion of coke, and a reduction in the amount of dust produced.

In fig. 6 (p. 25) some Trzynietz agglomerates are illustra
(4 and 5).

II. Agglomeration Plant at Giessen.

At this plant, belonging to the Gewerkschaft Giessener Bra
steinbergwerke (formerly Fernie), equipped with only one calcir
drum, 2 metres in diameter and 35 metres long, and no cooling dr
the principal material dealt with is the manganese ores from the c
pany's own pits, but recently fine spar from Neunkirchen has also b
dealt with. The calcination of the manganese ores is not carried o
much for the purpose of converting the powdery ore into larger lur
as for the purpose of removing the high content of water (abou
per cent.) in order to decrease the costs of carriage to the ren
... in Rhenish Westphalia, Lorraine and Luxemburg

The rich and poor ores supplied are mixed together, so that after drying the mixture contains on an average about 20 23 per cent Fe and 20 per cent Mn, and forms the so called "Ferme ore," which has been in great demand for a long time

The results of two recent analyses of dried Ferme ore and Ferme agglomerate respectively are given below

Complete analysis of Ferme ore (after removal of the mine moisture, which equals about 25 per cent. of the ore)

31·98 per cent	ferric oxide (Fe_2O_3)	[illegible] per cent Fe		
29·04 ,,	manganese dioxide (MnO_2)	18·36 ,, Mn	}	[illegible] per cent Mn
2·82 ,,	manganous oxide (MnO)	2·18 ,, ,,		
9·35 ,,	alumina (Al_2O_3)			
0·16 ,,	titanic acid (TiO_2)			
14·97 ,,	silica (SiO_2)			
0·209 ,,	phosphoric acid (P_2O_5)	0·091 per cent P		
0·078 ,,	sulphuric acid (SO_3)	0·031 ,, S		
0·070 ,,	arsenious acid (As_2O_3)	0·046 ,, As		
0·77 ,,	sodium oxide (Na_2O)			
0·52 ,,	potassium oxide (K_2O)			
0·13 ,,	magnesia (MgO)			
0·258 ,,	lime (CaO)			
0·266 ,,	baryta (BaO)			
0·051 ,,	copper oxide (CuO)	0·041 per cent Cu		
0·015 ,,	lead oxide (PbO)	0·014 ,, Pb		
0·365 ,,	zinc oxide (ZnO)	[illegible] ,, Zn.		
0·102 ,,	cobalt oxide (CoO)	0·080 ,, Co		
0·48 ,,	carbonic acid (CO_2)			
8·09 ,,	chemically combined water			

Total 100·024 per cent

Complete analysis of Ferme agglomerate

37·60 per cent	ferric oxide (Fe_2O_3)	26·31 per cent. Fe		
9·91 ,,	manganese dioxide (MnO_2)	6·27 ,, Mn	}	22·30 per cent Mn
20·70 ,,	manganous oxide (MnO)	16·03 ,, ,,		
10·31 ,,	alumina (Al_2O_3)			
0·60 ,,	titanic acid (TiO_2)			
16·94 ,,	silica (SiO_2)			
0·231 ,,	phosphoric acid (P_2O_5)	0·102 per cent. P		
0·163	sulphuric acid (SO_3)	0·065 ,, S		
trace . .	arsenic acid (As_2O_5)	trace As		
0·21 per cent	sodium oxide (Na_2O)			
1·43 ,,	potassium oxide (K_2O)			
0·34 ,,	magnesia (MgO).			
0·38 ,,	lime (CaO).			
0·30 ,,	baryta (BaO)			
0·056 ,,	copper oxide (CuO)	0·045 per cent Cu		
0·019 ,,	lead oxide (PbO)	0·018 ,, Pb.		
0·425 ,,	zinc oxide (ZnO)	0·342 ,, Zn		
0·117 ,,	cobalt oxide (CoO)	0·092 ,, Co.		
0·05 ,,	carbonic acid (CO_2).			
0·31 ,,	combined water.			

Total 100·091 per cent.

The content of manganese dioxide was calculated from the cont of available oxygen 1·82 per cent.

Comparison of the two analyses shows amongst other things t agglomeration has resulted in a not inconsiderable increase of the i and manganese contents, mainly because not only has the mine moist been removed, but the combined water has also been reduced from 8·0 0·31 per cent, in fact almost completely removed. The reduction in carbonic acid from 0·48 per cent. to 0·05 per cent. is also worthy of no

Economy in the freightage costs is effected by the fact that inst of 15 tons of crude ore, only 10 tons of agglomerate have to be tra ported. The freightage for crude ores and agglomerates amount about 35 M. to Rhenish Westphalia, 40 M. to Lorraine and Luxembo Fine Westphalian flaming gas coals from the Ewald mine are u for the coal-dust firing. They contain 14 to 16 per cent. ash, ha calorific value of 6500 to 6800 calories, and cost about 14·50 M. per at the agglomeration plant. On an average, the coal consumptio about 15 per cent. of the yield of agglomerate, so that the fuel c are $0·15 \times 14·5 = 2·17$ marks per ton, or $2·17 - 0·92 = 1·25$ marks per higher than the corresponding costs at Trzynietz.

Wages: fifteen men are employed at 29 pf. per hour, the t daily wages (two 12-hour shifts) being therefore 42·20 M. or 42·2 25 = 1055 marks per month.

With a monthly output of 3000 tons, 1 ton agglomerate cost wages $\frac{1055}{3000} = 0·35$ M.

Consequently the costs for fuel and labour are $2·17 + 0·35 = 2·52$

No figures are to hand with regard to the remaining costs, b may be taken that the total cost of production of 1 ton of agglome exclusive of sinking fund and interest charges, will be at least 4 M

During occasional runs on the agglomeration of Neunkirchen spathic ore the plant is much less economical, its monthly ou being only 1500 tons. Since, however, this fine spar (of 3–5 mm. g size) can scarcely be smelted because of its high content of impurities as pyrites and zinc-blende (the zinc content often b as high as 4·5 per cent.), its treatment in tube ovens is profitab view of the 30 to 38 per cent. loss, complete desulphurisation, considerable volatilisation of zinc which takes place during the pro Generally a valuable product containing about 47·5 per cent. Fe 11 per cent. Mn is obtained in the form of strong, coarse lumps.

Various agglomerates of Giessen manganese ores and Neunkir

PETERSSON AGGLOMERATION PLANT AT LÅNGSBANSHYTTAN, SWEDEN[1] (PLATE IV.)

This plant was built and put into operation in 1908 by the Lesjöfors Aktiebolag at Långshanshyttan (Dalarne province), with the object of providing a charge richer in iron for the Långshanshyttan blast furnaces in order to ensure an increased yearly output of pig iron, lower charcoal consumption and lower costs of production.

The principal material available is the magnetic concentrate from Persberg. Since only 2800 tons of sintered concentrates were required annually, the method usually adopted in Sweden of sintering pressed briquettes appeared to be too costly and it was decided to carry on a direct sintering in a calcining furnace patented by G. O. Petersson, and applied with excellent results at Dalsbruk, in Finland, since 1905.

Preparation.—Since the supply of ore from Persberg could not always be depended upon with certainty, a small dressing plant was erected to work up the accumulated heaps of poor magnetic iron ore in order to provide the necessary quantities for the calcining furnaces. The poor ore is first broken to 6 mm. in a stone breaker, then worked up in a ten-stamp battery, and finally concentrated in the Ekman and Markmann[2] patent magnetic concentrator, the iron content being raised from about 32 per cent. to 62 per cent.

The arrangement of the dressing plant by the Maschinenfabrik Morgårdshammar of Smedjebakken, Dalarne, has given good results in practice.

The Petersson calcining furnace (Plate IV.),[3] constituting the agglomeration plant, consists of five flat arches, K, J, H, G, F, built of refractory bricks, and arranged alternately from top to bottom, dividing the furnace into five compartments linked up with each other. Charged in at the top, the concentrates gradually roll through the compartments, become sintered together and are discharged at the bottom as irregular shaped lumps illustrated in fig. 6 (p. 25) at 6.

[1] G. Franke, "Mitteilungen über einige neuere schwedische Anlagen und Verfahren für Aufbereitung und Brikettierung von Eisenerzen und Kiesabbränden," *Glückauf*, Essen, 1908, No. 41, p. 1457 *et seq.* *See also* G. Ekman.

[2] These ore separators have been illustrated and intimately described in the papers mentioned above.

[3] The diagrams are taken from G. O. Petersson's paper "Om rostning af pulverformiga malmer och slagger samt deras användning," *Bihang till Jernkontorets Annaler* (Stockholm, 1905). In this treatise experiments on the roasting of various ores and slags are described in detail, including analyses of the materials concerned.

Calcining and sintering is effected by the counter-current of furnace gas and air passing through the concentrates.

The blast-furnace gas enters at the top through the pipe A ir pre-heater B, and most of it passes down the pipe C into the ig chamber D. A small portion of the gas branches from B in narrow tube R, whence it is led to the opposite narrow side furnace and applied to the pre-heating of the air, which enters th the heated tube E, circulates under the arch F over the hot fi ore, and then passes through the system of channels L into the ig space D. A damper is provided in the channel L for regulatir air supply.

From the space D the gases are led under the arch G to the op side of the furnace, then upwards through the turning channel the arch H, then in a similar manner to the arches J and K, an finally drawn off to the chimney.

The ore concentrates, denoted by dots, remain on the various a of the furnace during the whole operation, lying in conical l The portions indicated by small crosses roll over these heaps down the vertical side channels, and follow the roasted ma indicated by small circles. This occupies such a position i furnace that, so long as it is powdery and hot, it can trickle of its accord from arch to arch when ore is drawn off from the de opening at the bottom. If the temperature of the calcining cha gets high enough to sinter the ore into lumps, assistance must be by means of rakes, which is, however, a very simple operation.

Output.—The furnace at Långsbanshyttan has been built fo output of 10 tons in 24 hours, or about 2800 tons per annum. the commencement of operations in the middle of June 1908 the daily output has varied between 12 tons (half of the blast-fu charge) and 3 tons (scarcely one-tenth of the charge) according t stock of ore.

Only blast-furnace gas is applied for heating, and about 15 per of the total available quantity is ample for the production of a calcined concentrate. Heat losses by radiation are very slight, the chimney gases are relatively cold. The Petersson furnace is suitable for heating with producer gas, and can therefore be used advantage at dressing plants not attached to a blast-furnace plant

Attendance.—Three men per shift can attend to the work of Petersson furnace and the Westman calcining furnace with six charge openings installed at the ...

required before its installation the Petersson furnace only requires the services of one man

Formerly the working costs exclusive of sinking fund and interest (about 30,000 kr.) amounted to between 0·75 and 1·5 kr. averaging 1·25 kr. per ton of concentrate. Compared with the costs of the Gröndal method these figures are very low. Up to the present no costs for fuel and repairs have entered into the question at Långsbanshyttan, since there was no other scope for the utilisation of the blast-furnace gases and the oven is so strongly built that there is no perceptible wear of the brickwork and arches after a year's working. Expenditure for repairs, therefore will only become necessary in the remote future.

The agglomerate consists partly of irregular lumps of various sizes, and partly of particles sintered together. It is to all intents and purposes red hæmatite. Since the concentrates are free from sulphur, it is not usually necessary to carry the sintering beyond the point required to produce about 50 per cent agglomerate, and to obtain the remainder in granules below 0·6 mm.

An exception to this is met with in the case of the Varp concentrates from the Langrusvan, a chalky ore containing 62 per cent Fe and 0·248 per cent S. This material must be calcined until the product contains only 0·025 per cent S and as little as 20 per cent. of fine material.

A series of daily tests has proved that the porosity of the agglomerates is 40 to 50 volumes per cent., a value which is very high.

In a sintered mass which had been intentionally calcined for a prolonged period the porosity showed a value of 26·5 per cent.

Up to the present, the results of smelting have been excellent. No inconveniences have arisen in the blast furnace owing to the smelting of a material containing considerable quantities of fines. The proportion of ore in the charge can be increased by the use of agglomerates. This had previously been found to be true in the case of briquettes made from similar concentrates on an experimental scale. With 50 per cent. agglomerate in the charge it was possible to increase the ore by 20 per cent. with the same amount of charcoal but this has been found to be increasingly difficult of late. At the same time, the costs of production of the pig iron are considerably diminished.

After such favourable results, there can be no doubt that sintering and agglomeration of magnetic concentrates in the Petersson furnace will find a much wider application.

APPENDICES TO VOLS. I. AND II.

I. Further Results of Tests on Pitch and Coal Briquettes

The results of experiments given in Vol. I. (p. 34 *et seq.*, p. 19 *et seq.*, and p. 296 *et seq.*) are supplemented by the following tables, for which the author is under obligation to Dr Aufhauser of the Thermo-Chemical Testing and Research Laboratory, Hamburg. For several years this laboratory has made a study of all kinds of fuels, more particularly of coals, coal briquettes, and pitch from Germany and other countries (especially England).

The results of tests on about 200 English briquetting pitches showed the following average results:—

(*a*) Ash, 0·2 to 0·5 per cent., averaging 0·3 per cent.

(*b*) Binding materials or substances soluble in carbon disulphide, 6·91 to 81·3 per cent., averaging 73·6 per cent.

(*c*) Softening point, 56° to 69° C.

(*d*) Melting point, 62° to 77° C.

Results of tests on coal briquettes made in Dr Aufhauser's Thermo-Chemical Testing and Research Laboratory, Hamburg.

Description	Crude Coal (Pitch, Briquettes). Water	Ash	Combustible Material	Carbon (C)	Hydrogen (H)	Oxygen (O) and Nitrogen (N)	Sulphur (S)	Calorific Value.	Yield of Coke	Volatile Constituents (excl. Water).	In 100 Parts Pure Coal or Combustible Material. Carbon (C).	Hydrogen (H).	Oxygen (O) and Nitrogen (N).	Sulphur (S)	Calorific Value.
						COAL-TAR PITCH									
..	.	1·0	99·0	91·8	4·8	2·2	0·4	8487	47·8	52·2	92·8	4·8	2·0	0·4	857
		0·6	99·4	92·2	5·1	1·9	0·2	8622	39·8	60·3	92·7	5·2	1·9	0·2	867
						RHENISH-WESTPHALIAN PIT COAL BRIQUETTES.									
Emden Mine .	1·4	6·7	91·9	79·3	4·6	6·2	1·4	7638	porous 73·4	25·2	86·7	5·0	6·8	1·5	831
Engelsburg Mine	0·9	8·2	90·9	..	..	.		.	..			..	..	..	..
Fröhliche Morgensonne Mine	1·5	8·9	89·6	.		.		7545	.	..	.	.	..	..	843
,, ,, ,,	1·0	6·4	92·6	82·0	4·2	5·5	0·9	7824	porous 80·2	18·8	88·6	4·5	5·9	1·0	845
Herkules Mine	1·2	7·6	91·2		..	.	..	.	.	.		..	..	..	
,, ,,	1·3	8·9	89·8		.	.	.	..	.	..	.	..	..	..	
Neuholland ,,	1·9	7·0	90·2	77·8	4·5	6·3	1·6	7499	porous 70·6	27·5	86·3	5·0	6·9	1·8	832
,, ,,	1·9	7·9	90·2	.				..	..	..	..		..		
Prinz Regent ,,	1·1	9·8	89·1	.		.		.	.	.		.	..		
Rosenblumendelle Mine	2·2	7·4	90·4					7638	caked 82·8	15·0	..		..		846
Schürbank ,,	1·6	7·3	91·1	.		.	.		..	..	..	..	..		
Siebenplaneten ,,	1·3	8·3	90·4	80·5	4·1	4·6	1·2	7628	caked 83·7	15·0	89·0	4·5	5·2	1·3	833
Rheinau egg briquette ..	2·7	5·7	91·6	83·0	3·9	4·0	0·7	7713	81·6	15·7	90·6	4·2	4·4	0·8	849
Dahlhausen Deep Mine	1·0	7·8	91·2		.		..	7678	..	..	..	..	..	..	842
Schürbank ,,	0·8	7·8	91·4	.	.	.	..	7781	..	.	..	..	..	..	851
Eintracht Deep ,,	1·0	8·0	91·0	.	.	..		7851	83·8	15·2	..	..	..	..	863

Description	Crude Coal (Pitch, Briquettes): Water	Ash	Combustible Material	Carbon (C)	Hydrogen (H)	Oxygen (O) and Nitrogen (N)	Sulphur (S)	Calorific Value	Yield of Coke	Volatile Constituents (less Water)	In 100 Parts Pure Coal or Combustible Material: Carbon (C)	Hydrogen (H)	Oxygen (O) and Nitrogen (N)	Sulphur (S)	Calorific Value
Coal Briquettes from German Briquette Factories importing English Coals															
	3.1	8.0	88.9				0.8	7402							8346
	2.7	8.0	89.3				1.[illegible]	7328							8224
	3.7	10.0	86.3				0.8	7084							8220
	2.3	8.4	89.3				0.[illegible]	7335							8232
	2.0	10.1	87.9				1.1	7229	caked 78.8	19.2					8237
Egg briquettes	3.6	6.9	89.5					7605							8521
,, ,,	5.5	6.4	88.1	79.[illegible]	4.0	4.0	0.9	74[illegible]0	slightly porous 74.4	21.1	89.9	4.5	4.6	1.0	8467
,, ,,	2	7.0	90.7	81.3	4.3	4.[illegible]	0.9	7506	porous 73.[illegible]	24.0	89.5	4.8	4.7	1.0	8387
,, ,,	4.3	8.3	87.4	78.9	4.1	3.3	1.1	7397	slightly porous 74.5	21.2	90.[illegible]	4.7	3.8	1.2	8493
,, ,,	2.2	7.5	90.3				0.9	7609	caked 81.[illegible]	15.6					8441
Whole ,,	3.6	5.0	91.4	82.4	3.5	4.5	0.[illegible]	7636	caked 82.2	14	90.2	3.8	5.0	1.0	8378
Egg ,,	2.9	6.2	90.9				1.1	7699							8390
,, ,,	2.8	9.6	87.6				0.9	7330	caked 75.4	21.8					8381
,, ,,	2.7	6.4	90.9				0.9	7648	slightly porous 78.6	18.[illegible]					8431
,, ,,	1.3	7.3	91.4				1.1	7682	slightly porous 80.[illegible]	17.8			..		8413
English Coal Briquettes															
Merthyr	1.8	7.2	91.0	8[illegible].4	3.7	4.0	0.9	7712	sintered 8[illegible].7	18.5	90.5	4.1	4.4	1.0	8486
Arrow	1.4	12.1	86.5					73[illegible]0	caked 8[illegible].7	14.[illegible]					8552
Crown	1.3	5.8	92.9					7925	porous 78.6	20.1					8639
Star	1.3	6.6	92.1	82.6	3.9	4.7	0.9	7634	caked 84.4	14.3	89.7	4.2	5.1	1.0	8296
Swan	2.3	12.4	85.3					7156	caked 87.5	15.2					8382
Atlantic	1.5	7.6	90.9	83.3	3.8	3.0	0.8	7716	caked 87.4	16.1	91.6	4.2	3.3	0.9	8496
Pacific	1.3	11.1	87.6	80.6	3.5	3.2	0.3	7347	sintered 86.7	12.0	92.0	4.0	3.7	0.3	8390
Anchor	0.7	12.5	86.8	76.6	4.1	5.1	1.0	7211	caked 89.6	16.7	88.2	4.7	5.9	1.2	8318
Arrow	0.8	11.5	87.7					7402	slightly porous 83.5	15.7					8440
Lion	1.3	11.0	87.7					7432	81.8	16.9			..		8483
Brown Coal Briquettes of Central Germany															
Agnes Flessa	15.6	4.1	80.3	51.4	4.1	23.8	1.0	4511	40.0	41.4	64.0	5.1	29.7	1.2	5788
,, ,,	11.9	4.7	83.4	53.5	4.3	24.7	0.9	4771	42.3	45.8	64.1	5.2	29.6	1.1	5806
Henriette (Lower Lausitz)	12.7	6.5	80.8	52.3	4.2	23.6	0.7	4666	42.1	45.2	64.7	5.2	29.2	0.9	5787
Ilse (Lower Lausitz)	12.5	5.5	82.0	52.7	4.4	24.5	0.4	4885	40.6	46.[illegible]	64.3	5.4	29.8	0.5	5808
Union	10.8	5.5	84.2					4862							5871
Selling Agency of the Saxon brown-coal mines, Leipzig	13.9	10.8	75.3				2.9	4663							6808
	16.0	12.0	72.0					4617							6648
	11.7	11.7	76.6					4928							6625
Rhenish Brown-Coal Briquettes															
"Union," for suction gas producers	12.0	6.1	81.9	55.6	4.2	21.6	0.5	4858	..		67.9	5.1	26.4	0.6	6019
	11.7	5.4	82.9	55.2	4.4	22.7	0.6	4822	43.6	44.7	66.6	5.3	27.4	0.7	5902
	16.4	19.5	64.1	..	..	..	..						..	..	

II. Cost of Heat.

The following is an extract from an excellent article entitled "The Calorimetric Valuation of Coals in its Technical and Economic Importance,"[1] by Dr Aufhauser of Hamburg.—

"In the economic valuation of coal it becomes necessary to find a relationship between the market value of the coal and its calorific value. By market price is understood the price per 1000 kgs. (ton) delivered. This price is determined by the prime costs and the transport conditions, and generally amounts to between 15 and 30 marks per ton. By calorific power is understood the energy of combustion contained in 1 kg. of coal. The relationship between these two magnitudes is determined by calculating the cost of a certain definite number of heat units. A suitable basis is the cost per 100,000 cals., and this is denoted by the phrase 'cost of heat.'"

It is calculated as follows —If, for example, a coal of the calorific power 6500 cals. costs 17 marks per ton in Hildesheim, it is possible to buy 6500×1000 calories for 17 marks, and 100,000 calories of this coal would cost therefore $\frac{17\ 00}{6500 \times 1000} \times 100{,}000 = 26\ 1$ pf. The general formula is cost of heat $= \frac{\text{price per ton}}{\text{calorific power}} \times 100.$

In the case of pit coals the "cost of heat" varies between 20 and 30 pf.; in Hamburg, for example, it averages 25 to 26 pf. It seldom falls below 20 pf. for pit coals, but is generally below this value for brown coals and brown-coal briquettes. The following table shows the cost of heat for various coals at different places :—

Supplied in	Origin and Description of Coal.	Calorific Power in Calories	Price per Ton.	Cost of 100,000 Calories.
		per kg	M.	Pf.
Hamburg . . .	Charlesworth .	7160	18·75	26·2
,, . .	German rough bituminous .	7360	18·50	25 2
,, . .	German briquette . .	7609	18·60	24 5
,, . . .	Brown-coal briquette . .	4322	9·00	18·7
Altona . .	Bothal Westhartley . . .	6853	18·50	27·0
,, . .	Rhine—Elbe and Alma	7713	19 85	25 7
Lubeck . . .	German locomotive .	7958	19·40	24 4
,,	Sieved Westhartley . .	6801	17·40	25·6
Flensburg . .	Scotch Lochgelly	5669	10·00	17·6
,, .	Ewald No. 3 nuts . . .	7504	21·20	28·3
Rendsburg . . .	Hargmoor nuts. . . .	7142	15·32	21·5
Nienburg a. W. . .	Bassinghausen . . .	6093	11 00	18·2

The cost of heat also plays a part in the calculation of freight costs based on increased costs for coals of higher value. In this respect a reply given by the Saxon Ministry to a memorial from persons connected with industry is of

[1] Contained in *Industrieverein für den Regierungsbezirk Hildesheim*, April 30th, 1909.

interest, and it is to the effect that in the determination of the freightage for coals and brown coals the higher tariffs for coals permit of a greater number of units of heat being transported for the same amount of money.

A direct valuation of coal according to the cost of heat, which would be a fixed unit price per 100,000 cals., is however not absolute, since, in addition to calorific power, the nature of the coal and its behaviour in the fire must also be considered in its choice. When the choice of a suitable coal for a particular method of firing has once been made, naturally the coal with the highest calorific value would be preferred. In order to ensure this advantage in the purchase of coal, there are two forms of contract for its supply in which the calorific value is made the basis for the valuation of the coal. They are as follows:

1. The "Calorie contract," in which an average calorific value is fixed. A certain variation, *e.g.* 50 cals. above or below, influences the price of the coal in such a way that a reduction is made for each 50 cals. below and an increment of price for each 50 cals. above the contract figure.

2. The "Guarantee contract," in which a minimum calorific value is fixed definitely. A certain small allowance, *e.g.* 1 to 3 per cent. below, can be permitted in isolated cases, but if such diminution recur or exceed 3 per cent., the purchaser is at liberty to reduce the price or to refuse the delivery.

With regard to the practical results of such endeavours, the case of Switzerland can be cited as a typical example. This country is compelled every year to set apart a certain proportion of the national expenditure for the purchase of energy in the form of coal from foreign countries. The railways of the Swiss Confederacy have therefore carried out continuous determinations of the calorific values of their coal supplies (briquettes) for a number of years, and have paid the suppliers on the results of their tests. This example has been followed by the private railways, the shipping companies, etc., of Switzerland, and in fact they have combined to form a "Coal Union of Swiss Transport Companies." In Germany similar attempts had been made at a still earlier date, but the efforts were only individual until the last few years, when the whole question has gained a real interest on various grounds. At first the technical authorities (boards of public works, electricity works, etc.), traffic companies, and large industrial users determined to order their coal in such a way as to more or less permit of payment on its calorific power. If such attempts become general and spread to moderate-sized industries, the proper solution appears to be in combination for the common purchase of coal.

Such attempts for the common interest have been made on several occasions in South Germany, especially by the Union of South German Industries in Mannheim. Further, the Verein für Feuerungsbetrieb und Rauchbekämpfung of Hamburg has been brought into prominence as a combine of industries having for its object the inspection and improvement of the firing industry in all its branches.

All these endeavours are to be praised, since the present state of industry demands the greatest possible reduction in the production and working costs, and as the above examples show, this can be best effected by a combination of common interests.

REFERENCES TO LITERATURE.

1. *Zeitschrift des Vereines deutscher Ingenieure*, 1906, p. 956.

2. *Zeitschrift fur Dampfkessel- und Maschinenbetrieb*, 1908, No. 31.

3. *Jahresberichte des Vereins fur Feuerungsbetrieb und Rauchbekampfung, in Hamburg.*

4. Dr Aufhauser, *Vorlesungen uber Brenstoffkunde und Verbrennungsprozess*, Hamburg, 1908.

III. E. Helbing and J. Hemmerling's Patent Methods for the Production of Pressed Peat Blocks (D.R.P. 139,625 and 179,045).[1]

A method combining these two patents has in the last few years given excellent results on an experimental scale. It consists in mixing the rough wet peat with 1 to $1\frac{1}{2}$ per cent. milk of lime and 0·1 per cent. of pyrolusite, removing the enclosed air and the bulk of water by compression, with subsequent drying of the resulting blocks by exposure to the air or by means of waste steam.

The admixture of the peat with milk of lime (Helbing, D.R.P. 139,625) assists briquetting by reducing the slimy nature of the material, while the small addition of pyrolusite (or some similar manganese compound which readily evolves oxygen) promotes readiness of ignition and burning.

The Hemmerling press is designed to remove as completely and as rapidly as possible the air and water from such wet materials as peat, coal slimes, etc., while retaining the whole of the solid constituents.

In principle, the arrangement consists of a suitable press whose mould has a base and cover of hollow plates, the air and water being forced into the interior through fine holes in the plate walls in contact with the material without loss of solid particles.

Fig. 77 shows diagrammatically in section the scheme as applied to a simple hydraulic press, while figs. 78 and 79 show the plan and cross section of a hollow plate.

The hollow plate, conveniently made of cast iron, is provided with a number of deep longitudinal grooves *b*, whose total cubical capacity just about corresponds to the volume of liquid contained in a layer of material to be compressed. The bridges between the grooves are pierced by fine vertical holes *c*, which widen out towards the top and open into the horizontal cross grooves *d*.

Method of Working.—A drilled plate *f*, forming the base of the frame-shaped mould *g*, is laid on the press plate *e*. The mould is now filled up to a certain definite height with the moist material, and a hollow plate is then inserted. A sieve plate *f* is now laid upon the hollow plate, followed if necessary by a piece of cloth before the introduction of the second layer of

[1] Owned by the Torfholz-Gesellschaft m. b. H. Dresden, Pillnitzer Street 80, where a small experimental plant is installed. The method is also patented in England, No. 10,187, 1906, and No. 25,616, 1901.

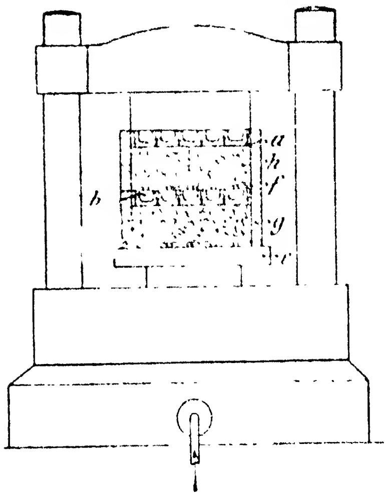
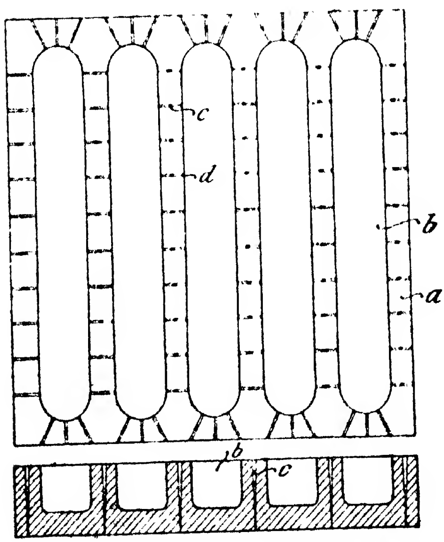


FIG. 77. Diagram of a hydraulic press with Hemmerling's hollow plate. Section



FIGS. 78 and 79.—Hollow plate. Plan and cross section

material. In this way as many layers as the height of the press will permit are built up. Of course a hollow plate could be placed under the lowest layer of material if it is considered advisable.

When the press comes into operation the motion of the plunger causes all the air and liquid to be driven out of the various layers through the channels *c* and the cross grooves *d* into the grooves *b* of the hollow plates *a*.

In these grooves there exists a certain pressure which rises as the plunger of the press is driven upwards, and as a result the water removed is prevented from carrying solid particles with it. To a certain extent air is driven out of the grooves *b* on increasing the pressure, but this is not possible in the case of the water, since the grooves are of sufficient capacity to retain the whole of the water forced out of one layer.

On a working scale, the production of pressed peat blocks by the above method is carried out as follows. The wet turf cut from the moor, without any preliminary treatment whatever, is intimately mixed in a mixing machine with 1 to $1\frac{1}{2}$ per cent. milk of lime and 0·1 per cent. of pyrolusite, and freed from a part of its high water content in a preliminary hydraulic press having a mould 1 square metre in section and 50 cm. high. The cake is then again loosened in the mixing machine and supplied to the main press.

The moulds of the main press are divided so as to produce 28 blocks of $20 \times 20 \times 8$ cm. in size at one operation, and are provided with small wheels so that they can be moved about readily. The complete operation of pressing lasts about 60 seconds, divided up as follows: 10 seconds for introducing the moulds, 40 seconds for the compression, and 10 seconds for removing the moulds. The output, therefore, amounts to $60 \times 28 = 1680$ blocks per hour, or 13,440 per shift of 8 hours, or 40,320 blocks per day of three shifts.

Since the weight of the finished block is at least 500 grams, the output of a press is about 20 tons per day.

The blocks are removed from the moulds by hydraulic power. In this condition they always contain 58 to 60 per cent. water, a figure which corresponds to the amount in wet compressed blocks of brown coal. The water content is further reduced until it reaches a value of 30 per cent. at a maximum.

The diminution of the 80–85 per cent. water contained in crude turf to 58–60 per cent. by hydraulic compression does not appear to be very considerable, but the following calculation will show that, as a matter of fact, by far the greater proportion of the original water content has been removed: 100 kgs. turf with 85 per cent. water contain 15 kgs. dry peat and 85 kgs. water; 100 kgs. "pressed peat" with 60 per cent. water contain 40 kgs. dry peat and 60 kgs. water. 100 kgs. turf, therefore, will yield $\frac{100 \times 15}{40} = 37·7$ kgs. of "pressed peat blocks," which contain 15 kgs. dry material (40 per cent.) and 22·7 kgs. of water (60 per cent.). Consequently $85 - 22·7 = 62·3$ kgs. of water, equal to 73·3 per cent. of the original water content, has been removed from the crude turf by hydraulic pressure.

Subsequent drying is either effected artificially in drying chambers heated

by waste steam from the steam-engine, or by exposing (in summer) to the air in drying sheds. Steam drying takes 24 to 36 hours, air drying about 6 days.

This combined method for the production of compressed peat blocks has not up to the present found working application on the large scale, but it is shortly to reach this stage.

With regard to the probable installation and working costs, the following is taken from a calculation of the profits made by the owners of the patent rights (Torfholz Ges. m. b. H. Dresden) for the author:—

(a) Costs of Installation

of a peat briquette factory for an output of 10 double loads (100 tons) per 24 hours, with a steam boiler of 150 square metres heating surface, 1 steam engine of 120 H.P., 2 mixing machines, 5 hydraulic presses, drying arrangements and accessories, including buildings, chimney, erection, etc., and a working capital of 50,000 marks.

Total (*a*)	300,000 M.

(b) Working Costs

per double load (10 tons) peat briquettes.

Rough turf (about 40 cubic metres	15·00 M.
Workmen's wages	40·50 ,,
Materials (lime, pyrolusite, etc.)	9·50 ,,
Total	65·00 M.

Consequently the costs per 10 double loads (100 tons) per day of 3 shifts =	650·00 M.
Additional charges for manager, 3 foremen, 3 firemen, turf, oil, etc., for firing =	50·00 ,,
Pure working costs =	700·00 M.
To this must be added for depreciation of the capital costs (2 per cent. on buildings, 10 per cent. on machines, engines and boiler, 25 per cent. on belts, tracks, tools, etc.), daily	37·20 ,,
Total (*b*) =	737·20 M.

(c) General Expenses.

Special erection work, daily	129·50 M.

(d) Total Working Costs.

Total (*b*)	737·20 M.
Total (*c*)	129·50 ,,
Grand total	866·70 M.

The costs of production per double load are therefore 86·67 M.

With the costs of production at this high figure, a reasonable profit can

only be obtained by a correspondingly high selling price, and whether or no this can be obtained for peat blocks containing 25 to 30 per cent. of water and a not inconsiderable amount of ash depends upon the existence of extremely favourable conditions (see Vol. I. p. 618 *et seq.*).

Mixed Briquettes of Peat and Anthracite or Pit Coal Dust can be prepared by the same method without the use of other binding materials with good results, but it must be possible to bring together these various materials, which usually occur in districts more or less remote from each other, at a very low cost.

IV. Briquetting of Coal Slimes by J. Hemmerling's Patent Method (D.R.P. 179,045).

The wet slimes as obtained from the coal washery, the settling or clarifying tanks, are simply compressed under a pressure of 500 kgs per sq. cm. in a hydraulic press by the method described on p. 204 *et seq.* No admixture is made, and the water contained in the slime is forced out down to a residual content of about 10 per cent. with the aid of hollow plate illustrated in figs. 78 and 79.

In the experimental plant of the Torfholz-Gesellschaft of Dresden, the author was present at a number of tests on the briquetting of washery slimes carried out during the summer of 1909. The tests were so successful that the water pressed out was almost perfectly clear. While the freshly pressed briquettes were not very strong, they soon hardened in the air.

According to the report of Dr Friedrich Schmidt of Dresden, briquettes of various origin prepared in this way gave the following results:—

	Coal Slime Briquettes from		
	General Blumenthal Mine.	Flaming Gas Coals.	Bituminous Coals.
Water	8·56 per cent	4·40 per cent	4·29 per cent.
Ash	11·34 ,,	28·76 ,,	27·37 ,,
Calorific value	6511	4904	5194

Coal washery slimes have also proved suitable for binding fine coals of not over 2 mm. in grain size. The mode of operation is the same.

V. Briquetting of Flue Dust by Hemmerling's Method (D.R.P. 179,045).

The briquettes are produced from flue dust intimately mixed with a small quantity of lime water in a hydraulic press, as described above, under a pressure of 500 to 700 kgs. per sq. cm. Removal of the air contained in the dust is effected by means of the Hemmerling hollow plates. To ensure complete binding the pressed blocks are stored in the air for 5 to 6 days.

Examination of a number of flue-dust briquettes made in this way, in the light of the requirements laid down on p. 14, has given rise to written reports describing very favourable results.

Dr Friedrich Schmidt of Dresden determined the specific gravity of the briquettes as 2·14 to 2·35, the porosity or capacity for absorbing water as 20·73 to 28·12 volumes per cent., and found that after $\frac{3}{4}$ to 1 hour's exposure to the action of a current of steam at 140 to 150° C. the briquettes had undergone scarcely any change in external appearance.

In the Königlichen Mechanisch-Technischen Versuchsanstalt, Dresden, several flue-dust briquettes were subjected to the action of gases, both rich and poor in carbon dioxide, and corresponding in composition to various blast-furnace gases at temperatures between 800 and 1000° C. The result showed that in no case did the strength fall below that of a simultaneously exposed briquette which had been made at the Königshütte O.S. by the sand-lime method.

At the same time the new Hemmerling method shows the advantage over this process of being considerably cheaper.

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